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Evaluation of Septic Leachate Detection

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AN EVALUATION OF SEPTIC LEACHATE DETECTION

by

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Contract No. 68-03-3057

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16. ABSTRACT

An evaluation of septic leachate detection (SLD) technology was performed. The results indicated that the conceptual basis of SLD devices is unproven and the devices have not been evaluated properly to determine their utility as a screening device in facility planning for rural lakeshore communities. Even if this issue is neglected, the cost-effectiveness of SLD surveys is marginal

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxics Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Research Laboratory is that component of EPA's Research and Development program concerned with preventing, treating, and managing municipal and industrial wastewater discharges; establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and assessing the nature and controllability of releases of toxic substances to the air, water, and land from manufacturing processes and subsequent product uses. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Recognizing that nearly eighty (80) percent of the municipal wastewater facilities needed by the year 2000 are located in small communities and that the per capita cost of those facilities are far higher in these rural communities than in urban areas, there is a need to improve facility planning in rural regions to avoid unnecessary capital expenditures. This document analyses and discusses one of the newly developed techniques purported to improve facility planning for rural lake communities.

Francis T. Mayo, Director
Water Engineering Research Laboratory

ABSTRACT

This study subjects Septic Tank Leachate Detection (SLD) technology to a critical analysis, focusing on these primary issues: the proposed hypothesis of its functioning; its status of development and performance to date; and its cost-effectiveness. Functionally, these devices measure fluorescence and, in some cases, conductivity. The sources of the compounds which register on these types of measurement are widespread and non-specific to septic tank leachates. There is negligible evidence to support the assumption that distinct and identifiable plumes could exist in zones of groundwater entry into lakes, except in a very few specialized instances such as perched water flow over confining bedrock.

Facts which indicate that SLD devices are only in an early developmental stage include the lack of false negative ratio quantification, i.e., missing a plume when one exists. A statistical analysis of existing SLD survey data shows that the false positive ratio to be in the neighborhood of 30 percent. No useful screening tool can be reliably employed until the false negative ratio is established to be very low and the false positive ratio is cost-effective. A method of quantifying these factors is proposed.

Finally, available cost information does not appear to be particularly favorable to SLD surveys due to the limited effective distance from the shoreline to the septic tank-soil absorption system (25 meters) and the need for limited, follow-up sanitary surveys.

This report was submitted in partial fulfillment of Contract No. 68-03-3057 by Urban Systems Research and Engineering, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from 1980 to 1983, and work was completed as of September, 1983.

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Special thanks go to the Project Officers and staff of the Water Engineering Research Laboratory of the Environmental Protection Agency, Robert Bowker, James Kreissl and James Cox. Their guidance and direction have been essential in ensuring the quality of the research and of this report. The research would not have been possible without the cooperation of the developer, manufacturers, and clients of SLD surveys. The assistance of Larry Feldman of Goldberg Zoino Associates was also invaluable.

The development of this report required key contributions from a number of past and present USR&E staff members and consultants. Dave Burmaster, Cynthia Ernst, Margaret Jensen, Valerie Bradley, John Best, and Susan Farrell all participated in all various aspects of the report. Finally, the efforts of Cynthia Daley in the final production have been exceptional.

SECTION 1

INTRODUCTION

1.1 PURPOSE

Under the small community pollution abatement program, the Environmental Protection Agency's Municipal Environmental Research Laboratory is reviewing several techniques which may improve the wastewater planning process for non-sewered areas. The purpose of this report is to evaluate Septic Leachate Detection (SLD) as a method for identifying areas where on-site wastewater systems adversely impact lake water quality.

The evaluation focuses on the following questions:

1. Is the SLD hypothesis supported by wastewater treatment, groundwater movement, water quality monitoring, and limnologic theory?

2. Do SLD surveys improve mass balance analysis methods?

3. Is SLD currently in the research development or demonstration phase?

4. Are SLD surveys more cost-effective or do they provide more information than shoreline, mass balance, or other traditional or non-traditional evaluation methods?

1.2 THE PROBLEM

Faced with the deterioration of water quality, authorities often assume that effluent from on-site domestic wastewater systems is a primary source of contamination. This assumption should be carefully verified before a community commits itself to an expensive sewage collection system designed to completely eliminate effluent discharges to the lake.

Documenting a cause and effect relationship between deteriorating surface and groundwater quality and the use of on-site systems has long been a challenge. Wastewater facility planning techniques available for the task include review of local health department records, mail or door-to-door sanitary surveys, shoreline and windshield surveys, identification of other potential contaminant sources, hydrologic and geohydrologic studies, and ambient water quality monitoring. While

conventional shoreline surveys often reveal direct discharge drains, storm drains, wetlands, unusual concentrations of algae or rooted aquatic plants, and tributaries there is no convenient or generally accepted way to verify the existence, location, or impact of subsurface effluent plumes using conventional planning techniques.

Traditionally, wastewater facility planners gather information using some combination of the above techniques, and then use mass balance analysis to estimate the potential impact of domestic wastewater on the lake. The question addressed by this report is whether SLD surveys could make a significant contribution to such evaluations by either improving or expediting the current approach.

1.3 DEFINITION OF SEPTIC LEACHATE DETECTION (SLD)

Septic Leachate Detection (SLD) is based on the theory that effluent from on-site wastewater systems forms detectable subsurface effluent plumes which travel through the groundwater system and emerge intact into a lake. The diagram in Figure 1 has been used in numerous SLD reports to illustrate this theory of subsurface effluent plume movement.

Developing a methodology for proving the existence of a subsurface effluent plume entails three preliminary steps. First, the water quality variables to be used as indicators of the effluent plumes must be selected. Second, the criteria to be used for determining the existence of plumes must be set. These criteria should take the form of recognizable and reproducible deviations from background concentrations of the indicator water quality variables. Third, standard procedures for data collection and analysis must be established.

In theory, data for such surveys could be collected using any number of ambient water quality monitoring techniques. However, verifying the location of plumes emerging along the shoreline with traditional grab sampling procedures presents unique problems. However, a monitoring device which <u>continuously</u> measured levels of the desired water quality indicators and instantly recorded changes in their concentrations could be used to pinpoint emerging subsurface effluent plumes. Traditional grab samples could then be analyzed to verify the presence or absence of such plumes.

At the time of this writing, there are two commercially available water quality monitoring devices designed specifically for use in SLD surveys. Environmental Devices Corporation, (ENDECO) manufactures the ENDECO Type 2100 Septic Leachate Detector (Septic Snooper™), which uses both fluorescence and conductivity as indicator parameters. K-V Associates has recently introduced the Model 15 Septic Leachate Detector (Peeper Beeper™), which monitors contaminants solely by fluorometric analysis. When data collection on this analysis began, only the Septic Snooper™ or a modified Septic Snooper™ owned by K-V Associates were used for SLD surveys. The results of this report, then, are based on surveys completed with those devices, and not the Peeper Beeper™.

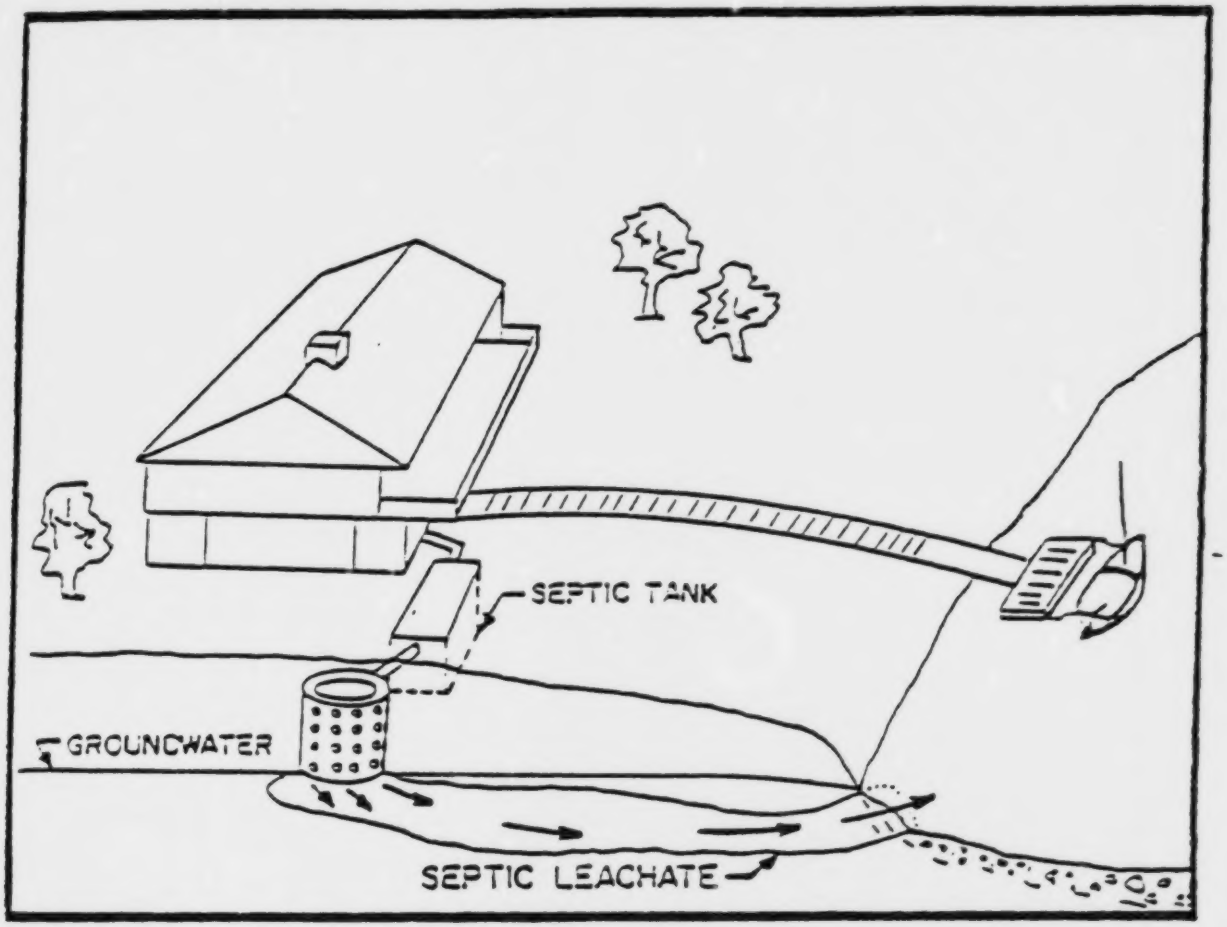

Figure 1. ILLUSTRATION OF SEPTIC SYSTEM LEACHATE PLUME ENTERING LAKE (EMI, 1976).

USEPA Region V has sponsored a number of SLD surveys as part of its Seven Rural Lakes project. Based on this experience, the SLD is described at length in the Final Generic Environmental Impact Statement for Wastewater Management in Rural Lakes Areas. The description has been reproduced in its entirety in Table 1.

1.4 RESEARCH METHODOLOGY

The findings of this report are based on analysis of information from numerous sources:

- General literature in the disciplines of groundwater movement, on-site wastewater systems, ambient water quality, and limnology
- Published and unpublished SLD survey reports
- Observation of a shoreline survey conducted using the Septic Snooper™
- Participation in a Septic Snooper™ training course.
- Interviews with the Septic Snooper™ developer, manufacturer, users, and client communities
- Consultations with experts in groundwater hydrology, limnology, ambient water quality monitoring, on-site wastewater systems, and statistical analysis.

Information about the SLD concept was gathered during the initial phase of the research. A detailed literature review and consultations with experts in the various scientific disciplines were used to determine whether the SLD hypothesis is supported by wastewater treatment, groundwater movement, water quality monitoring, and limnologic theory. The water quality data generated by SLD surveys were also analyzed to determine whether the survey results met the basic criteria for scientific proof: repeatability and statistical significance. The draft report was then submitted to experts for reveiew and comments. The conclusions of this report are based on the findings of these analyses.

Section 2, that follows, presents the conclusions and recommendations. Section 3 analyzes the theoretical assumptions underlying the SLD concept, while Section 4 reviews field experience with the Septic Snooper™. Appendix A presents data from early SLD Surveys, and Appendix B describes the statistical methodology used to analyze that data. The comments submitted by the developer and manufacturer of the Septic Snooper™ can be found in Appendix C, while Appendix D presents the comments made by reviewers of the draft report. Finally, Appendix E lists the individuals contacted in the preparation of this report.

TABLE 1. DESCRIPTION OF SEPTIC LEACHATE DETECTION (WAPORA, 1983)

Currently available septic leachate detectors can be used to locate groundwater inflows or surface runoff conveying domestic wastewater into lakes. The operational theory of the detector depends on the assumptions that fluorescent organic materials are present in wastewater and that inorganic chemicals will be present in wastewater at higher concentrations than in ambient groundwater or surface water. Detection of both increasing fluorescence and increasing conductivity in water drawn by pump from a shoreline provides tentative evidence of the presence of domestic wastewater. Because of the high sensity of their fluorometers, currently available detectors can rapidly locate groundwater effluent plumes and wastewater in surface runoff where wastewater is otherwise undetectable. This tool proved to be invaluable in studies that addressed the impacts of on-site systems on lakes studied for the Seven Rural Lake EIS's.

The septic leachate detector is subject to certain limitations that must be recognized in its use and in interpretation of the data it generates. The most significant limitation is that it cannot quantify the strength of wastewater in a sample or body of water. The organic and inorganic parameters that it monitors can be transported through soil and water quite independently of other wastewater constituents. Even the fluorescence and conductivity are recorded in relative, not quantitative, units. In order to quantify the concentrations of nutrients, bacterial, or other wastewater constituents, flow through the meter can be subsampled or samples can be collected by conventional means for later analysis. The advantage of the detector is that it permits collection of samples in suspected effluent plumes so that random sampling is avoided.

Aside from the limit on quantification, septic leachate detector surveys are subject to false positives and false negatives. Most of these potential errors are due to the dynamic nature of the natural systems involved and to variability in wastewater characteristics. False positives can be caused by:

- Naturally fluorescent decay products from dead vegetation. Swamps, marshes and peat deposits can leach tannins, lignins and other organic compounds that fluoresce in the detection range of the fluorometer. The conductivity measurements provided by the detector are intended to differentiate such signals, but in practice dilution may eliminate detectable conductivity changes expected from wastewaters, thus making a wastewater plume appear to be the same as natural decay products.

- Sediment or air drawn through the detector can cause dramatic changes in the monitor readings. This is usually noted by the operator and recorded on the recorder tape.

- Eddy currents carrying large wastewater or bog plumes can appear to be individual plumes from on-site systems.

TABLE 1 (continued)

The more serious errors are false negatives since they may indicate no problem where actual problems might exist. Notable false negatives are:

- As mentioned above, high dilution of wastewater in lake or groundwater may reduce conductivity differences to the level of normal background variations.

  The absence of conductivity differences will cause the detector to electronicly mask fluorescence signals that are detected.

- Mixing of lake water by wind and waves can disperse leachate very rapidly so that normally strong effluent plumes can be missed altogether. The time it takes for leachate to accumulate along a shoreline to detectable concentrations is dependent on several, so far unstudied, factors.

- Fluctuations in lake level can slow or even reverse normal groundwater flow, temporarily eliminating leachate emergence at a shoreline.

- Groundwater recharge by rainfall, snowmelt or irrigation will also affect the dynamics of leachate movement.

- Seasonal use of dwellings may result in only periodic emergence of leachate at a shoreline.

Due to these factors, the data generated by septic leachate detectors has to be carefully interpreted before it can be considered to be useful information. Interpretation is aided by supplementary data collected or recorded before, during, and after the shoreline scan as noted:

Before

- watershed boundaries
- groundwater aquifer characteristics
- groundwater flow as determined by meters or other methods
- soil types
- wetlands and other sources of organic decay products in the watershed
- locations of surface malfunctions identified by aerial photography interpretation
- information on design, usage, and performance of onsite systems if available
- changes in lake elevation.

TABLE 1 (continued)

During

- weather conditions - especially wind, speed and direction, and recent rainfall
- lake stratification and surface currents
- observed non-wastewater sources of fluorescence or conductivity such as culverts, drainage ditches, salt storage areas, landfills, abundant organic material in near-shore sediments

- observed direct discharges
- likely proximity of on-site systems near shoreline
- operational mishaps such as stirred up sediments, air drawn through meter and engine backwash
- sensitivity and zero adjustments for fluorescence and conductivity channels
- frequent notation of visual meter readings
- location, time, and conditions of water sample collection.

After

- water sample analysis results.

Because of the possibilities for error and the many factors influencing the result of septic leachate detection, the validity of surveys rests heavily on the experience, knowledge, and judgment of the surveyor. Until additional evaluation is made of the factors influencing survey results, septic leachate surveys will be eligible for Construction Grants funding only when:

1) the person in charge is experienced in operation and maintenance of the detector model being used. At least two weeks of field experience is necessary assisting someone who is already expert with the model,

2) the person in charge is present during any shoreline scans that are reported,

3) data is interpreted by a person who has a professional background in limnology, and

4) approximate wind speed and direction are noted during the survey and reported.

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TABLE 1 (continued)

Septic leachate detectors should prove to be valuable monitoring tools for communities managing shoreline on-site systems. Purchase of detectors will be eligible for Construction Grants funding. Grantees will be required to show that comparable instruments are not available on a timely basis from other nearby grantees. Funded instruments will be made available to other grantees.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

Summary

The septic leachate detection (SLD) concept rests on two assumptions about the behavior and characteristics of septic effluent in lake shore regions. The first assumption is that septic leachate plumes usually exist in the groundwater and often migrate toward lakes. This assumption is supported by both groundwater theory and empirical evidence. The second assumption is that septic leachate plumes emerge into lakes in a discrete, intact, and identifiable form. While groundwater theory supports the condition that the plume may be identifiable, in many instances it will not be.

For a plume to be identifiable it must be of sufficient strength, quantity, and velocity to resist dilution; it must be of sufficent cross sectional area to insure, with a reasonable probability, that the SLD device will pass through the plume; and the SLD device must measure a water quality parameter which is consistently representative of septic system leachate. There are problems with each of these conditions.

Plume velocity and concentration are both inversely related to plume cross sectional area. Because of this, groundwater theory predicts that a given plume may range from relatively concentrated with a small cross sectional area and high velocity, to relatively dilute with a large cross sectional area and low velocity. As a result, the strong plumes could be easily missed because of their small cross sectional area. The large plumes, on the other hand, could be too dilute to detect, and are quickly dispersed into the lake water. Groundwater theory also predicts that the maximum plume velocity is .002 cm/sec. The ability of plumes to resist dilution in the littoral zone at this rate is questionable.

There is also a problem with the parameter used to indicate the presence of the plume. SLD devices currently on the market measure a combination of conductivity and fluorescence, or simply fluorescence. There are many natural sources of flourescence other than septic leachate plumes in the lake environment that could theoretically actuate the device.

Practical experience does not support the concept of the SLD surveys either. In the fifteen SLD surveys reviewed for this study, there is

little empirical evidence supporting the assumption that septic leachate plumes are distinct and identifiable. There has been no controlled research to document the false positive and false negative rate of SLD surveys. What limited field evidence there is, suggest that the false positive rate is above 30%. Such a high rate is a strong indication that the device is often actuated by natural phenomena other than the presence of a septic leachate plume.

False positives result in an overestimation of the contribution of septic leachate to water quality problems. In a screening tool such as this, they could lead the facilities planner to take so many grab samples to prove the existence of a plume, that the cost advantages of using the device to screen for potential problems are lost.

There is no field documentation of false negative rates. Since each false negative represents a pollution source which has been missed by the survey, it is imperative that the frequency of false negatives be relatively small. Otherwise, the screening tool can grossly underestimate the septic leachate problem and cause planners to make poor decisions about wastewater treatment needs. The rate of false negatives is independent of the rate of false positives and must be documented through both laboratory and field experiments before the data from SLD surveys can be considered valid.

SLD surveys are designed to screen for septic leachate plumes. Grab samples of the lake water must be used to confirm or deny the presence of a plume. SLD surveys are relatively expensive when compared to sanitary surveys but may be less expensive than detailed groundwater monitoring at individual lots.

As presently espoused, SLD surveys can only locate septic leachate plumes which are from systems within 25 meters of the lake and which remain discrete and identifiable after reaching the lake. An underlying assumption is that identifying these plumes is important. However, for many lakes the major source of nutrient loading may be from systems which are not included in the SLD survey because they are set back more than 25 meters from the shoreline or because they have dispersed plumes.

Key Conclusions:

1. There has been no laboratory or field documentation of the false negative rate.

2. There has been no laboratory documentation of the false positive rate.

3. Limited information from field surveys implies a false positive rate of greater than 30%.

4. There are serious questions as to whether SLD plumes are large enough or remain distinct and intact in lakes long enough to be detected.

5. There appear to be many non-plume sources of fluorescence which actuate the SLD device, causing false positives.

2.2 RECOMMENDATIONS

SLD surveys should not be used in facilities planning until the false negative rate has been established and deemed acceptable.

Because the SLD concept is intriguing, there will probably be additional private sector research aimed at developing an accurate, reliable, and cost effective SLD device. The following list of recommended research efforts has been developed to this end.

1. Carefully planned dye or tracer tests should be conducted in conjunction with SLD surveys in several lake shore areas with different geologic and soil conditions, to provide the data necessary to establish the false negative rate.

2. Double blind laboratory experiments should be conducted under controlled conditions to demonstrate the SLD device's, reliability and repeatability. Table 2 presents an example experimental design.

3. A set of SLD survey procedures should be developed and tested. This would provide a much higher degree of standardization for one-time studies of a single lake, multiple studies of the same lake over time, and one-time and multiple studies of several lakes.

4. Experiments should be conducted in the field to determine the true impact of environmental conditions on the accuracy of SLD survey results. This could be done at the same location and time as the tracer dye tests suggested in No. 1 above. A field survey of a shoreline along which all septic systems are marked by a tracer would provide information on false negative as well as false positive rates. This type of test would also provide interesting insights into the role of the visual shoreline inspection in the SLD device's ability to identify septic tank leachate plumes.

TABLE 2 DOUBLE BLIND

CONTROLLED CONDITIONS EXPERIMENT
FOR
SEPTIC LEACHATE DETECTION (SLD) ACCURACY

Set up

Select a number of standard water samples, ranging in contamination level from distilled water to (possibly diluted) septic tank effluent. Example standards might include:

distilled water
tap water
background lake water
background lake water spiked with phosphate*
background lake water spiked with nitrate
background lake water spiked with coliform
background lake water spiked with chlorides
septic tank effluent diluted with lake water 1/100
septic tank effluent diluted with lake water 1/10

*all spikes should be to concentrations equal to 1/10 the septic tank effluent sample

Make up (a minimum of three) duplicate 15 gallon samples of each standard, randomly numbered from 1 - 10.

Experimental Procedure

An operator not familiar with the experimental set up should measure each sample using a full scale SLD device, recording both the inorganic and organic meter readings as well as the combined signal for each sample. Calibration can be handled in two ways. Either the calibration can be set as part of the experimental set up, in which case the results across operators can be compared, or, the individual operators can be asked to calibrate the SLD device based on initial trial measurements. In the latter case, the results across operators will not be comparable, however the impact of different calibrations on the results can be studied. The experiment should be conducted in both ways for the most complete results.

Analysis

The results should be analyzed in several ways to determine:

- The repeatability of SLD device readings on duplicate samples for the same operator and across operators.
- The ability of the SLD device to consistently distinguish between distilled water, background lake water, and diluted septic tank effluent, for the same operator, across operators, and with different calibrations.
- Which of the water quality components normally associated with domestic wastewater (e.g., phosphates, nitrates, chlorides, or coliform) has the greatest impact on SLD readings.

SECTION 3

SEPTIC LEACHATE DETECTION (SLD) CONCEPT

3.1 THE SLD CONCEPT

The first step in evaluating any new theory is to express it in clear terms. Numerous published and unpublished documents describe the SLD concept in varying levels of detail (e.g., IEP, Inc. 1980, ENDECO 1977 and 1979: K-V Associates 1978, 1979 and 1980: WAPORA 1983.

In their description of SLD surveys (Table 1) U.S. EPA Region V provides an excellent outline of the SLD concept:

> "The operational theory of the detector depends on the assumptions that fluorescent organic materials are present in wastewaater and that inorganic chemicals will be present in wastewater at higher concentrations than in ambient groundwater or surface water. Detection of both increasing fluorescence and increasing conductivity in water drawn by pump from a shoreline provides tentative evidence of the presence of domestic wastewater."

This SLD concept assumes that the following conditions exist.

1. Septic system effluent plumes form in the groundwater under soil absorption systems and travel more or less intact toward lake shores.

2. Once a septic system leachate plume emerges into a lake, it remains intact for a sufficient period of time to be detected. To be detected, the leachate plume must contain materials which are measurable with a fluorometer, and present at detectably higher concentrations that found in the lake water.

3.2 ASSESSMENT OF THE SEPTIC LEACHATE DETECTION (SLD) CONCEPT

In order to assess the theoretical validity of the SLD concept, the likelihood of meeting the two conditions is analyzed below.

Condition #1:

> Plumes of septic tank effluent form in the groundwater under soil absorption systems and travel more or less intact toward lake shores.

The existence of groundwater plumes from septic system is consistent with groundwater theory (Domenico, 1972) and has been documented by researchers measuring nitrate levels (Ellis, 1983), nitrates, phosphates and fecal coliform, (Luce and Welling, 1983), total carbon (Hirsh, 1983), nitrate and carbon (Rea and Upchurch, 1980) and viruses (ENDECO, 1977). Rea and Upchurch (1980) found that nitrates, phosphates, and chlorides move in response to different factors. This phenomenon implies that several parameters must be monitored in order to trace septic system plumes in the ground water.

In a recently published article, Gilliom and Patmont (1983) determined that phosphorus loadings to some lakes in the Puget Sound region are attributed to old septic tanks. Based on statistical analysis, the loadings are probably associated with only a few old systems located over confined aquifers in areas where shallow perched water keeps soils persistently saturated during the winter. This research was based on ground water monitoring of septic leachate plumes.

On the other hand Cook, et.al., (1978) found that most septic systems around two eutrophic lakes had clogged. The clogging caused effluent to rise to the surface and move to the lakes as overland flow rather than groundwater plumes.

It is also possible for groundwater to flow away from lakes and ponds rather than toward them.

While groundwater plumes of septic leachate may exist and may flow toward lakes, the condition is not universal.

Condition #2:

> Once a septic system leachate plume emerges into a lake, it remains intact for a sufficient period of time to be detected. To be detectable, the plume must contain materials which are measurable with a fluorometer and present at detectably higher concentrations than found in the lake.

Figure 2 illustrates the optimal operating conditions for the Septic Snooper™. The intake is held approximately one to two feet off the lake bottom, close to the shore. As the intake moves forward, it intercepts the septic leachate plume.

For any plume (groundwater, storm water, or stream) to be detectable in a larger water body, it must remain discrete and identifiable.

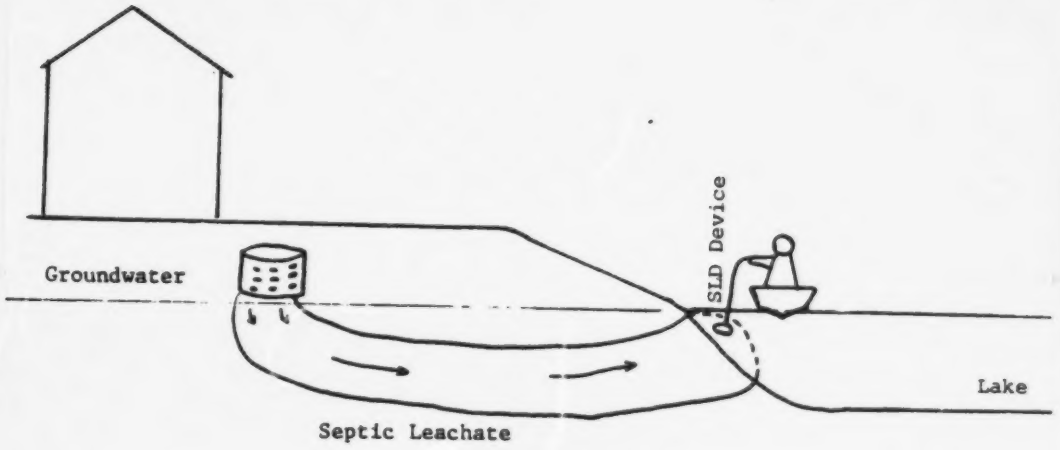


Figure 2. Optimal operation procedure for an SLD device.

Resisting dilution is particularly difficult in lake shore environment because velocities in the littoral area of lakes are quite rapid which causes rapid mixing. Only plumes with sufficient density, volume, strength, and flow rate can resist dilution by mixing. Each of these characteristics will be discussed in turn.

Density

Prentki, et al. (1979) point out that density differentials between a plume and the lake can be very important in the degree of plume dilution. If the plume is much denser than the lake water it will tend to sink and be less prone to mixing. If the plume is much less dense it will rise, forming a dispersed surface layer over the lake.

Solids content and temperature affect the density of any water sample. Of the two factors, temperature appears to exert more of an effect on plume density than dissolved or suspended solids content. In a study of storm water plumes, Prentki, et al. (1979) found that a temperature differential of only 1.1 ^{o}C caused 92% of the total density differential between the plume and the receiving water. This was true despite the fact that the storm water plumes contained nearly six times as many suspended solids as the lake water. Since septic leachate plumes should have a lower contaminant content than storm water, the importance of temperature on the relative density of the leachate plume will be even greater. Further, because groundwater temperatures vary less with season than those of lake water, the relative densities of effluent plumes and lake water may vary seasonally. Temperature variations associated with plumes were not reported in any of the SLD surveys reviewed.

Strength, Volume, and Flow

Plume strength, volume, and flow rate are all interrelated and are dependent on the strength, volume, and flow rate of the effluent discharged from the septic tank to the soil absorption system; the attenuation of contaminants in the soil; and dilution of the effluent in the groundwater as a result of both lateral and vertical dispersion.

In order to determine the likelihood of a leachate plume's having sufficient strength, volume, and flow rate to be detectable when it emerges into the lake, the following hypothetical analysis was developed. The septic tank effluent characteristics used are those characteristics recommended by EPA (1980) and found in Table 3. The analysis has been developed using the traditional engineering worst case approach. The conditions selected for this hypothetical example very much favor maintenance of a distinct and identifiable plume:

- Septic tank and leach pit discharge directly into the groundwater
- No pollutant attenuation in the soil
- Leaching area of 1 $meter^2$
- Leaching area profile to the lake of 1 meter
- Septic tank effluent flow rate of 700 liter/day

TABLE 3. CHARACTERISTICS OF TYPICAL RESIDENTIAL WASTEWATER[a]

Parameter	Mass Loading gm/cap/day	Concentration mg/l
Total Solids	115 - 170	680 - 1000
Volatile Solids	65 - 85	380 - 500
Suspended Solids	35 - 50	200 - 290
Volatile Suspended Solids	25 - 40	150 - 240
BOD_5	35 - 50	200 - 290
Chemical Oxygen Demand	115 - 125	680 - 730
Total Nitrogen	6 - 17	35 - 100
Ammonia	1 - 3	6 - 18
Nitrites and Nitrates	<1	<1
Total Phosphorus	3 - 5	18 - 29
Phosphate	1 - 4	6 - 24
Total Coliforms[b]	-	10^{10} - 10^{12}
Fecal Coliforms[b]	-	10^{8} - 10^{10}

[a] For typical residential dwellings equipped with standard water-using fixtures and appliances (excluding garbage disposals) generating approximately 45 gpcd (170 lpcd). (EPA, 1980)

[b] Concentrations presented in organisms per liter.

- o Leach pit 15 meters from shore of lake
- o Groundwater flow rate ranging from 1 to 0.2 meter/day
- o Soil Porosity of 20%
- o No dilution from groundwater or recharge
- o No lateral or vertical dispersion of the leachate plume.

The analysis which assumes no dilution, no pollution attenuation, and virtual direct discharge to the lake would be comparable to the situation studied by Gilliom and Parmont (1983) where they found high phosphorus loadings in lakes correlated with the presence of old septic systems located in areas with seasonally perched groundwater. While that study documented an impact on the lake and the existence of plumes in the groundwater, no data was collected to document whether plumes remained intact and identifiable in the lake.

If, as in the hypothetical example, the septic tank effluent reaches the lake at full strength, its detectability will depend on the velocity, quantity, and cross sectional area of the plume as it enters the lake. For a fixed quantity of wastewater, the rate of plume dilution in lake water will be inversly propotional to the plume velocity. If the plume enters at a high rate, it will be concentrated in a smaller area and be more likely to remain intact and identifiable, than if it enters at a low rate.

Another important consideration is the cross sectional area of the plume. The larger the cross section, the greater the likelihood that the SLD device will intersect it on a given pass of the shoreline. However, since cross sectional area and concentration are inversely proportional, plumes with large cross sectional area tend to be harder to detect because they are dilute and easily mixed.

Cross sectional area is also inversely proportional to velocity. For the fixed volume of septic tank effluent of 700 liters/day in the hypothetical example, the higher the discharge rate into the lake the smaller the cross sectional area and vice versa. At a relatively high groundwater flow rate of 1 meter/day, the cross sectional area of the plume would be 0.68 meter^2. At a lower groundwater flow rate of 0.2 meter/day the cross section area would be 3.4 meter^2. At these groundwater flow rates, the discharge into the lake is very slow: .005 to .0001 cm/sec. Even though the concentration of the plume in this worst case example could be a 1000 times the concentration in the lake water, the velocity and volume are very low, making the plumes very susceptable to dilution and rapid assimilation into the lake.

Plume Fluorescence and Conductivity

The SLD concept is based on the assumption that plumes have a higher concentration of dissolved organics and inorganics than the surrounding lake water. The existing SLD equipment displays a relative increase or decrease for fluorescence and conductivity, or in one machine, simply

fluorescence. Since both machines rely on fluorescence, only the specificity of that indicator is evaluated here.

The results of an analysis conducted on 35 samples "collected from septic tanks" (Peters 1982), suggest that while septic leachate plumes may fluoresce in the spectrum of interest, so do a number of organic materials in lakes not necessarily of wastewater origin.

3.3 CONCLUSION

While under many geohydrological conditions, septic leachate plumes migrate through the groundwater to lakes, the above analysis raises questions as to whether such plumes are likely to be of sufficient density, strength, volume, and cross sectional area to resist dilution and be consistently identifiable with a SLD device. Furthermore, there are numerous "naturally" occurring phenomena that could cause localized increases in lake water fluorescence unrelated to the presence of effluent. These natural phenomena could trigger the SLD device response.

SECTION 4

EVALUATION OF SEPTIC LEACHATE DETECTION (SLD)

4.1 INTRODUCTION

Although the total number of SLD surveys conducted between 1976 and the present is not known, it is estimated to be fewer than fifty. Septic Leachate Detection (SLD) Surveys have been conducted throughout the country in a variety of locations from Massachusetts to Washington state. Fifteen SLD surveys listed in Table 4 were reviewed for this study.

To date, SLD surveys have consisted of two components: a visual inspection of the shoreline and a real time measurement of conductivity and/or fluorescence using a SLD device. Since visual inspection and monitoring are used interactively, it is impossible to completely separate them. For example, SLD device readings indicating potential plumes may cause a surveyor to make more careful inspection of the shoreline for possible pollution sources. Similarly, upon observing a potential contamination source, the surveyor may make several passes with the SLD device in an effort to locate plumes.

The visual shoreline survey is an accepted wastewater planning tool in lake areas, comparable to a windshield survey used on the land. It is the use of the SLD device which differentiates a SLD survey from traditional methods. This evaluation will focus on whether the use of an SLD device as a screening tool improves the information gained from a shoreline survey (Section 4.2), the value of information gained in a SLD survey relative to that gained using other traditional or non-traditional methods (Section 4.3), and the relative costs of SLD surveys (Section 4.4) as compared to traditional survey techniques.

4.2 ACCURACY

There are two components to the accuracy of SLD surveys: the number of normal systems mistaken for failures, and the number of failing systems missed. The false positive rate is the ratio of apparent plumes detected by the SLD device which turn out to be indistinguishable from ambient water quality when sampled to the number of actual or true plumes identified. The false negative rate is the ratio of true plumes which are missed to the total number of true plumes that actually exist.

In general, false positives are caused by the presence of phenomena mimicking the characteristics of the phenomena being measured. False

negatives occur when the device being used is measuring the wrong characteristics or when conditions exist which hide or mask the characteristics of the phenomena being measured. Based on extensive field experience with SLD surveys, U.S. EPA Region V has developed a list of situations which cause both false positives and negatives. These were presented in Table 1.

Since the possible causes of false positives and negatives in a SLD survey differ, the two rates are not necessarily related. A high false positive rate does not necessarily imply a low false negative rate or vice versa. A device which does not measure its goal can easily have both a high false positive and a high false negative rate. In evaluating the accuracy of any measuring device, it is important to document both the false positive and negative rates independently.

When a SLD device is used to screen a lake for possible contamination sources, the impact of false positives is financial not environmental. False positives must be confirmed or rejected based on laboratory analysis of water collected from the possible plume. The higher the false positive rate, the more laboratory work is required, and the greater the SLD survey will cost. If the false positive rate is too high, the economic viability of the technique may be in question. However, the SLD survey approach could still be quite valuable even with a fairly high false positive rate.

The impact of false negatives in a SLD survey are environmental rather than financial. No extra costs are incurred, because the device does not identify any possible plumes to be sampled. However, adverse environmental impacts are possible if the SLD device fails to detect existing plumes entering the lake and water quality planners base treatment decisions on this erroneous information. This environmental impact makes a high false negative rate incompatible with the objectives of SLD surveys.

The SLD literature and survey reports were reviewed for information which could be used to document false positive and false negative rates under both controlled and field conditions.

SLD Accuracy under Controlled Conditions

While no method of measurement is perfect, certain accepted methods of measurement have been tested to determine how closely results reflect actual values. The three criteria most often used to evaluate measurement methods in water and wastewater are:

- Limits of Detection, which define the ranges of concentrations for which the method works
- Standard Deviation which defines the anticipated level of precision (that is, the difference between the measured value and the true value)
- Standard Error, which describes the method's accuracy (that is, does it measure the right phenomena).

These characteristics are defined in the laboratory under controlled conditions by repeated measurements of samples of known concentration. The user can then apply this understanding of a measurement method's limitations when interpreting field data.

There are no laboratory data defining the limits of detection, standard deviation or standard error of SLD devices in the published or unpublished literature identified and reviewed as part of this present study. A series of experiments documenting these key measurement method evaluation criteria should be conducted prior to field use of any measurement device. The lack of such experiments seriously limits the trustworthiness of data collected in the field.

SLD Accuracy Under Field Conditions

Sources of Data on SLD Device Performance: Reports of the 15 SLD surveys listed in Table 4 were reviewed for evidence that would substantiate the accuracy of SLD device readings in the field. The results of water quality analyses performed in conjunction with SLD surveys were presented in seven of the reports. In all cases, water quality analyses of non-contaminated or background samples were also reported. The data, as originally reported, are included in Appendix A as Tables A-1 to A-12.

In general, the water quality analyses presented in the seven SLD survey reports were performed on two categories of water samples: background and effluent plume. The background samples were collected in areas which were considered by the SLD survey team to be representative of the non-contaminated areas of the lake. Background surface water samples were collected either in the center of the lake or in areas along the shore line where SLD device readings indicated background water quality. Background groundwater samples were collected from areas considered by the SLD survey team to be free from the influence of septic effluent plumes.

The seven reports contain information on data collected at a total of nine lakes, two of which were monitored on two separate occasions, for a total of 11 data sets. Because the SLD surveys reviewed for this analysis were performed by a number of independent SLD teams over a period of time, there is considerable variation in the water quality parameters reported. The results frequently indicated concentration levels below the detection level of the laboratory tests. This analysis will focus on the parameters for which there were significant results.

In eight of the 11 data sets, values for either conductivity or total dissolved solids (TDS) were reported. In a different subset of eight data sets, levels of either total phosphorus (P) or phosphate-phosphorus (PO_4-P) were reported. While all of the studies reported some measure of nitrogen (N) content of the water samples, there was not a concensus as to which nitrogen form provided the best measure of contamination. Five different forms of nitrogen were measured, Total N, Kjeldahl-N, NH_3-N, NO_3-N, and NO_3+NO_2-N. Sodium, chlorides, total and fecal coliform were also reported.

Limitations of the Data on SLD Device Performance: The data collected by these independent SLD survey teams were not intended for use in a statistical analysis of the accuracy of SLD device readings. They therefore have several limitations when viewed in this new context:

1. In most data sets only a token number of background samples were analyzed. Only one study included a reasonable distribution with analysis of eight background and 19 plume samples reported. One other study reported findings on three background samples and 19 plumes. Of the remaining nine studies, four included analyses of only two background samples, and five only included analyses on one. Because of these data limitations, the statistical analyses below were performed using special techniques designed for use with small sample sizes. However, even these special techniques do not compensate for the lack of data. Because of this data limitation, the results of the statistical analysis presented later in this section tend to favor SLD test validity. Appendix B contains a detailed explanation of the statistical procedures used.

2. There are several types of errors which must be avoided when monitoring environmental parameters. False positive errors occur when the monitoring device indicates that contamination exists when in fact there is none. False negative errors occur when the device fails to identify contamination which is in fact there. Because of the way the data have been presented in the SLD survey reports, it is possible to make rough estimates of the rate of false positive errors (the probability that the water quality in a "detected" plume is in fact indistinguishable from background). However, since none of the SLD survey teams systematically gathered samples at shore line areas, which from visual inspection might have been expected to have plumes but where the SLD device readings did not indicate the existence of such plumes, it is not possible to estimate the level of false negative errors.

Questions About SLD Performance which Can be Addressed Given Data Limitations: A thorough examination of the performance of a SLD device should address all of the key issues of data validation and system performance: sensitivity, specificity, stability and reliability, zero drift, reproducibility, precision, response time, calibration, and accuracy. However the current analysis is restricted by the limitations of available data to addressing two basic questions:

1. Does the SLD device distinguish between contaminated and uncontaminated lake water?

2. Does a SLD device reading indicating a plume in the surface water correlate with the existence of a subsurface effluent plume in the shallow groundwater adjacent to the lake shore?

Does the SLD distinguish between contaminated and uncontaminated lake water? To answer this question the reported data was analyzed to determine if the concentrations of typical water quality parameters are consistently higher in plume samples when compared to background samples for:

a. All constituents
b. Certain constituents, or
c. Particular SLD surveys.

The Student's T-test was used as a measure of whether the observed differences between the background and plume samples were statistically significant. As with any evaluation, a decision criterion must be set establishing acceptable and unacceptable performance. In the case of laboratory analysis of water quality parameters, acceptable levels of performance have been establish through years of standard setting and are most often referenced in Standard Methods. (APHA, et al, 1980)

Typically, water quality monitoring equipment is expected to perform with a signifance level of less than 1%. Because the SLD devices as currently conceived are not meant to be quantitatively accurate, but rather screening devices, this evaluation will use a 30% significance level as the decision rule for what constitutes an acceptable performance in distinguishing between a contaminated and uncontaminated water sample. In other words, if the equipment performs satisfactorily using this test, the user can be fairly confident that the false positive rate will be about 30%.

Figure 3 illustrates graphically the frequency distribution for probabilities, Pr = 1%, Pr = 39%, and Pr = 92%. The first example (Pr = 1%) is illustrative of a data set were the concentrations in the plume sample are consistently sufficiently higher than those in the background samples to be considered statistically significant when the 30% decision rule is used. The second example (Pr = 39%) illustrates a set of data where although the mean concentration in the plume samples is still higher than those for the background samples, the difference is not sufficiently great to be statistically significant. The third example (Pr = 92%) illustrates a case where the plume and background samples are so similar as to be almost identical.

The results of this analysis are summarized in Figure 4 which presents the results for the six data sets which had at least two or more background samples.

A total of 31 constituent analyses were performed for these six data sets. Of these, six (19%) had a mean value in the plumes which was less than the mean value of the background. Nine (29%) did not meet the 30% decision rule, while 16 (52%) met the 30% decision rule.

TABLE 4. SLD SURVEYS REVIEWED

No.	Study Title	Short Title	STATE	DATE	Contractor	Client	DATA for Statistical
1	Shoreline Water Quality Survey, Lake Attitash	Lake Attitash	MA	Oct 1980	IEP, Inc.	Board of Health Amesbury, MA	YES
2	Investigation of Septic Leachate Discharges into Squam Lake	Squam Lake	NH	Sept 1977	ENDECO	Squam Lake Assn.	YES
3	Subsurface Leachate Discharges Into Johns Pond, Mashpee	Johns Pond	MA	Aug. 1976	Environmental Management Institute	Town of Mashpee	YES
4	EIS - Alternative Waste Treatment Systems for Rural Lakes Project Case Study Number 5 Otter Tail County Board of Commissioners, Otter Tail County, Minnesota FINAL Appendix B Septic Leachate and Groundwater Flow Survey, Otter Tail Lake, Minnesota	Ottertail	MN	Sept 1979	K-V Associates	Region V EPA	YES
5	EIS - Alternative Waste Treatment Systems for Rural Lakes Project Case Study Number 1 Crystal Lake Area Sewage Disposal Authority, Benzie County, Michigan Appendix C Investigation of Septic Leachate into Crystal Lake, Michigan	Crystal Lake	MI	Dec 1978	K-V Associates	Region V EPA	YES

TABLE 4 (continued)

No.	Study Title	Short Title	STATE	DATE	Contractor	Client	DATA for Statistical
6	Investigation of Septic Leachate Discharges into Lake Winona, Lake Winnepesaukee (and) Ossipee Lake	ERA Study	NH	Oct 1977	ENDECO	Estimation Research Associates, Inc.	YES
7	EIS - Alternative Waste Treatment Systems for Rural Lakes Projects Case Study Number 4 Steuben Lakes Regional Waste District FINAL Appendix D Septic Leachate and Groundwater Flow Survey, Steuben Lakes, Indiana	Steuben Lake	IN	Aug. 1979	K-V Associates	Region V EPA	YES
8	Septic Leachate Detection Study Lake Boon	Lake Boon	MA	Aug. 1979	ENDECO	Estimation Research Associates, Inc.	NO
9	Investigation of Septic Leachate entering Six Lakes in Carver County, Minnesota	Carver County	MN	June 1980	Swanson Environmental Inc.	Ellison - Philstrom Ayers, Inc.	NO
10	Septic Leachate Survey Detroit Lakes, Minnesota	Detroit Lakes	MN	Sept 1980	K-V Associates	Rieke, Carroll Muller, Inc.	NO
11	EIS - Case Study Number 3 Springvale - Bear Creek Sewage Disposal Authority, Emmet County, Michigan FINAL	Springvale	MI	Nov. 1978	K-V Associates	Region V - EPA	NO
12	EIS - Case Study Number 2 Green Lake Sanitary Sewer & Water District, Kandiyohi County, Minnesota	Green Lake	MN	Mar. 1979	K-V Associates	Region V - EPA	NO

TABLE 4 (continued)

No.	Study Title	Short Title	STATE	DATE	Contractor	Client	DATA for Statistical
13	Thurston County Lakes: Water Quality Analysis and Restoration Plan, 1982	Long Lake Patterson Lake	WA	Sept 1981	K-V Associates	ENTRANCO Engineers	No
14	Lemon Lake Diagnostic Feasibility Study, Draft Report	Lemon Lake	IN	May 1983	University of Indiana		No
15	Cedar Lake Restoration Feasibility Study	Cedar Lake	IN	Dec 1982	University of Indiana	Indiana Clean Lakes Coordinator	No

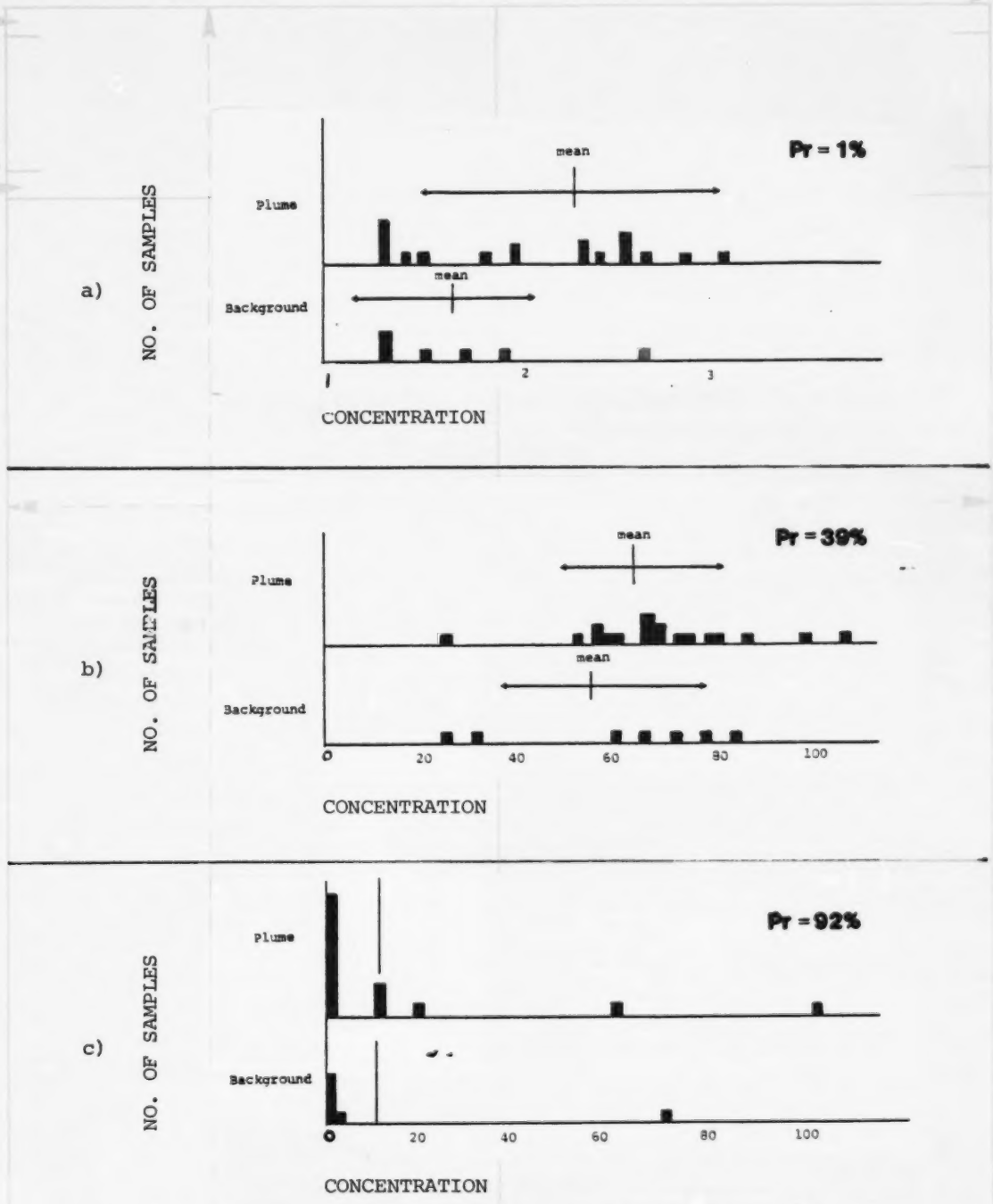


Figure 3. Sample frequency distributions and probabilities of significant differences using the student T-test.

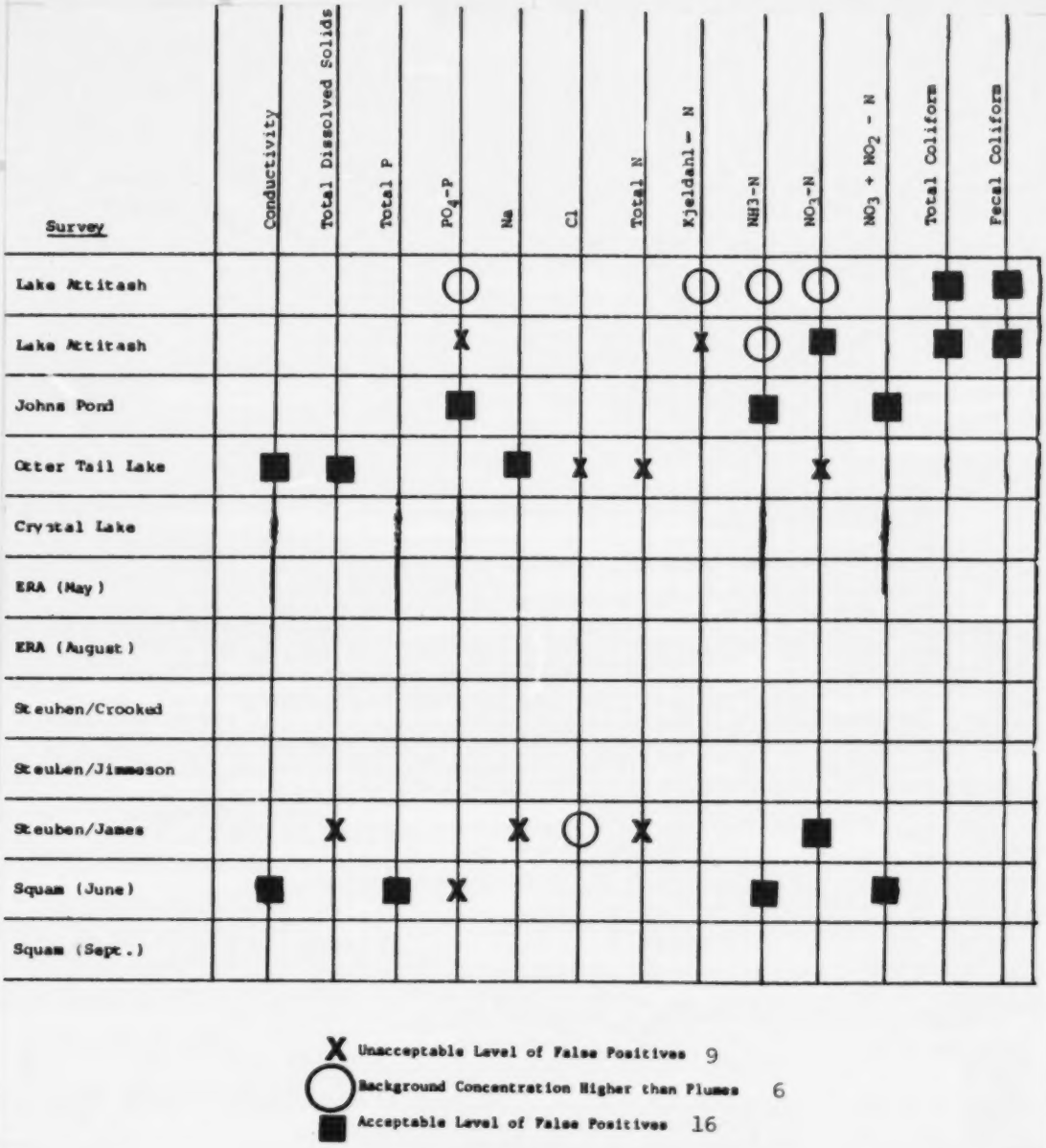


Figure 4. Results of student T-test using 30% decision rule and omitting surveys with only one background sample.

When the data from the surveys with only one background sample is included, the overall results are only slightly better. As shown in Figure 5, there were a total of 60 constituent samples, of which nine (15%) were negative, 14 (23%) did not meet the decision rule, and 37 (61%) met the 30% decision rule.

Does a SLD Device Reading Indicating a Plume in the Surface Water Correlate with the Existence of a Subsurface Effluent Plume in the Shallow Groundwater Adjacent to the Lake Shore? Shallow groundwater samples were collected during only two of the SLD surveys, and for one of these there was only a single background sample. The data were analyzed using the same Student's T-test approach used above. The results are summarized in Figure 6. As with the surface water analyses, there is very little consistency in the results and in only 50% of cases was the difference between the background and plume water quality statistically significant.

In conclusion, there is no laboratory data reported in the literature on false positive or false negative rates. The eleven data sets analyzed indicate that field experience with the SLD surveys does not support the hypothesis that the false positive rate is consistently 30% or less. There are no data available to document false negative rates.

4.3 COMPARISON TO OTHER METHODS

A new data collection method should become widely used only if it can:

(a) Gather useful data not generated by other methods
(b) Gather similar data in a much improved level of detail, or
(c) Gather similar data at a much lower cost than other methods.

This section will consider experience with SLD surveys, based on the first two of these criteria. The cost criteria is addressed in the following section.

In 1979, Peters and Krause (1980) arrayed different data collection methods used in the Rural Lakes Project, presented in Table 5, which compares seven methods for performance under seven criteria.

A review of this matrix reveals that SLD is a very specialized data collection method. It is meant to screen for a single factor in lake areas: the location of septic leachate plumes. Since most direct discharges to a lake can be identified through a visual inspection of the shoreline, the real asset of an SLD survey should be identification of septic tank leachate plumes entering a lake via groundwater seepage. As the matrix in Table 5 points out, this information cannot be confirmed through well sampling or non-traditional, aerial photographic methods. Such data could be collected using dye or tracer studies, although at a considerable expense.

The SLD survey is conceived as a method of screening a lake to determine where to conduct more detailed sanitary surveys and lake water

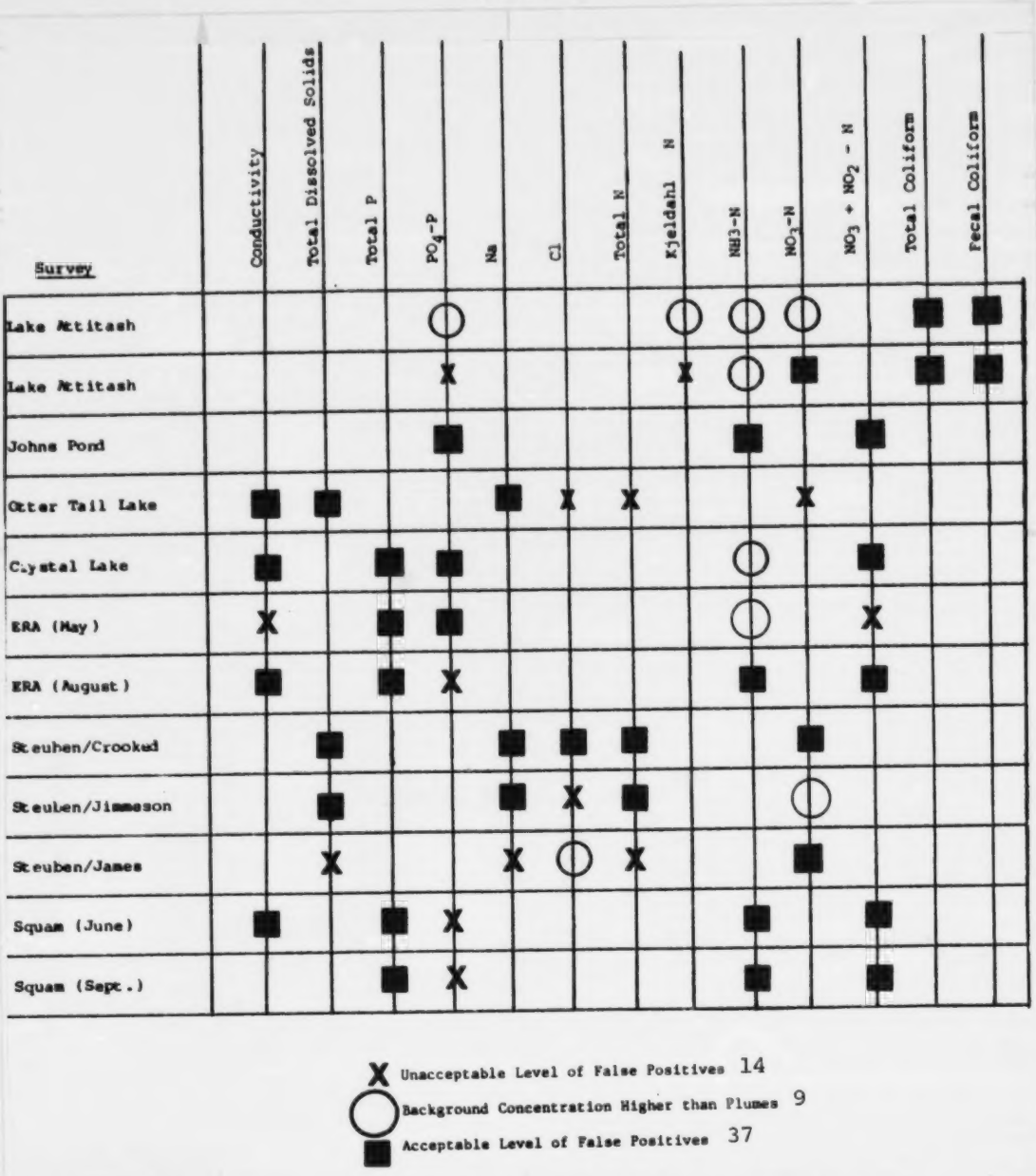
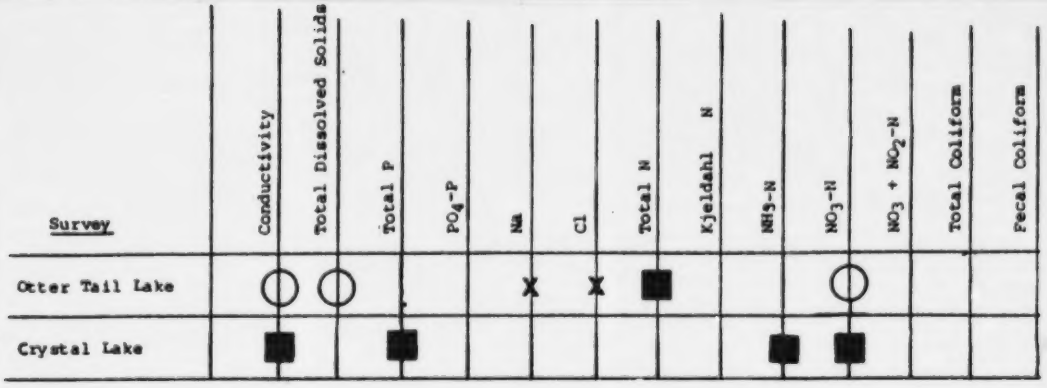


Figure 5. Results of student T-test using 30% decision rule using all survey data.



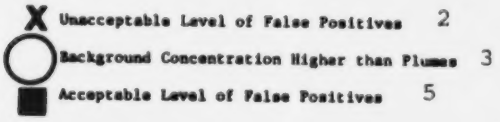

Unacceptable Level of False Positives 2
Background Concentration Higher than Plumes 3
Acceptable Level of False Positives 5

Figure 6. Results of student T-test using 30% decision rule for groundwater samples.

TABLE 5. INFORMATION PROVIDED BY ALTERNATIVE WASTEWATER PLANNING*

	Problems Covered						
			Discharge of Septic Tank Effluent to Surface Water				
Method	Surface Ponding of Septic Tank Effluent	Aquifer Contamination	Direct	Via Groundwater	Nearshore Plant Growth	Other Information	Relative Cost based on hypothetical lake situation discussed in text)*
Sanitary Survey	Locate		Locate		Locate and Identify	Household backups Occupancy Water use System design Public attitudes	10,800
Well Sampling (total and fecal coliform and NO_3)		Quantify					3,000
Aerial Photography	Locate		Locate		Locate	Land use Topography Housing counts	3,000
Septic Leachate			Locate	Locate			11,800
Shallow Groundwater Flow Monitoring				Identify source		Groundwater flow data for lake nutrient budgets	5,000
Shallow Groundwater Sampling		Quantify					3,100
Surface Water Sampling			Quantify	Quantify			3,100

*Peters and Krause (1980)

sampling programs. The field experience reviewed in the previous section indicates that SLD survey screening results in a relatively high rate of false positives which lead to extra follow-up work. More importantly, without any documentation on false negative rates there is little confidence that the screening process locates all possible sites where leachate plumes enter the lake.

Mass balance analysis is an alternative approach to evaluating the potential impact of septic tank leachate plumes on lake water quality. Mass balance analysis of nutrient loads is often used as the basis for wastewater facilities planning around lakes. This procedure involves first characterizing the watershed around the lake. Next, assumptions regarding the nutrient loading to the watershed from septic systems and other sources. Then, nutrient attenuation in the soil is estimated with the worst case being no attenuation. Using these assumptions, the total maximum annual nutrient load to the lake can be estimated, as can the proportion of the total load contributed by septic systems.

Unlike SLD surveys, the mass balance approach takes into account the total nutrient load to the lake from all septic systems in the watershed not those right on the lake. More importantly, mass balance takes into account the fact that nutrient loadings to lakes may have impacts, even if the individual plumes are not distinct and identifiable.

In summary, it does not appear that SLD surveys provide more accuracte information than traditional mass balance analysis.

4.4 COST

The cost reports by Peters and Krause (1980) shown in Table 5 are based on a hypothetical community with characteristics summarized in Table 6. These figures imply a cost of $45-$75 per household surveyed for a sanitary survey by which a community may be able to gather the following information:

- Surface ponding of septic tank effluent
- Quantity and frequency of household back-ups
- Direct discharges to the lake
- Near shore aquatic plant growth
- Occupancy
- Water use
- System design
- Public attitudes.

For purposes of this analysis, an average cost for sanitary surveys of $60 per household was used.

The cost figures developed by Peters and Krause (1980) have been used in the example presented in Table 7. This hypothetical example compares the costs for a SLD survey either independently, or in conjunction with a partial sanitary survey to the costs of a full-scale sanitary survey. The conditions for this hypothetical example are very favorable to SLD survey,

TABLE 6. HYPOTHETICAL EXAMPLE COMMUNITY DEVELOPED BY PETERS AND KRAUSE (1980)

Characteristics

Development located primarily near lakeshores

600 homes

Total shoreline of 9 miles

Sanitary surveys conducted for 25-40% of residences

Surface and shallow groundwater samples taken for nutrient and bacteriological analysis at 30 sites in the vicinity of effluent plumes entering the lake

Shallow groundwater and surface water sampling in conjunction with the shoreline septic leachate survey

Well water sampling in conjunction with a sanitary survey.

Estimated Costs (From Table 5)

Method	Cost	Units Covered	Cost/Unit
SLD Survey	$11,800	600	$19
Lake Water Sampling	$3,100	30	$300
Sanitary Survey	$10,800	600(25%-40%)	$54-$72, average $60

TABLE 7. COMPARATIVE COST ANALYSIS OF SLD SURVEYS AND SANITARY SURVEYS

This hypothetical example is based on the cost figures and hypothetical community presented by Peters and Krause (1980). In the community of 600 households, all have septic systems within 50-75 feet of the shore.

Estimated Unit Cost: SLD Survey = $19/home
Lake Water Sampling = $103
Sanitary Survey = $60/home

Case 1: Independent SLD Survey

Assumptions:

Survey entire lake shore with surface water sampling at 5% of the homes, at an overall cost of $25/home.

Cost:

(600 SLD surveys x $19/home) + (30 homes x $103/home) = $14,490

Case 2: SLD Survey with Partial Sanitary Survey

Assumptions:

No water samples are collected, but all detected plumes would be followed up by a sanitary survey.

90 potential plumes are assumed.

Cost:

(600 SLD Surveys x $19/home) + (90 sanitary surveys x $60/home) = $16,800

Case 3: Full Scale Sanitary Survey

Assumptions:

If SLD is not used, engineers will use professional judgement to select appropriate 40% of households to be surveyed.

Cost:

600 homes x 40% x $60/home = $14,400

because all 600 households have septic systems within 50-75 feet of the shore. Yet even in this favorable example, SLD survey costs are not significantly less than costs for a full scale sanitary survey.

4.5 CONCLUSIONS

There has been neither field nor laboratory documentation of SLD survey false positive or negative rates. Analysis of field data indicated that the SLD has not consistently performed at a false positive rate of 30% or less in identifying samples which are distinguishable from background due to elevated levels of various water quality parameters.

Because of the possible adverse environmental impact of missing an existing pollution source, documentation of the SLD false negative rate is essential. The false negative rate is independent of the false positive rate and must be documented separately. Until the false negative rate is documented and can be judged acceptable, the accuracy of SLD survey data must be considered suspect.

The data developed by a SLD survey is limited to homes within a short distance of the lake. Further, the SLD survey concept is based on the assumption that identifying only those septic leachate plumes that remain intact and identifiable in lake water is important. This assumption implies that the nutrient load from intact plumes is in some way more harmful to the lake than nutrient loads from septic leachate plume which, for whatever reason, have become too dilute to identify. In terms of long term ambient water quality protection, the location of identifiable plumes is less important than the overall nutrient load.

There is little or no cost incentive for using an SLD survey rather than a sanitary survey. Especially when one considers the many different types of information gathered in a sanitary survey compared to the single piece of information collected in an SLD survey.

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Appendix A

FIELD EXPERIENCE DATA AND ANALYSIS

Table A-1

WATER QUALITY GRAB SAMPLE ANALYSIS
(as presented in Attitash Lake Report)

IEP Sample Number	DWPC Sample Number (Station)	* Total Coliform	* Fecal Coliform	* Fecal Strep	** Total Kjeldahl-N	** Ammonia-N	** Nitrate-N	** Total P
Background A	A	20	10	-	0.71	0.02	0.0	0.04
	B	120	.10	-	3.04	1.90	4.3	5.40
Plume 1	1	3800	1500	-	0.81	0.03	0.0	0.20
Plume 2	2	180	110	-	0.73	0.0	0.0	0.17
Plume 3	3	360	180	-	0.82	0.01	0.0	0.13
Plume 4	4	300	140	-	0.67	0.0	0.0	0.08
Plume 5	5	300	140	-	0.70	0.02	0.0	0.07
Plume 6	6	80	40	-	0.65	0.01	0.0	0.03
Plume 7	7	2400	800	-	0.72	0.01	0.0	0.04
Plume 8	8	3000	1400	-	0.56	0.01	0.0	0.03
Plume 9	9	240	40	-	0.65	0.02	0.0	0.03
Background B	C	<20	10	-	0.64	0.01	0.0	0.01
	D	80	30	-	0.77	0.02	0.01	0.06
Background C	E	-	-	-	0.59	0.0	0.0	0.03
Background D	F	50	<10	-	0.83	0.03	0.7	0.04
Plume 10	10	200	100	-	1.05	0.0	0.1	0.09
Plume 11	11	400	20	-	0.67	0.01	1.0	0.04
Plume 12	12	300	80	-	0.48	0.0	0.1	0.04
	12A	400	20	-	-	-	-	-
	12B	20	<10	-	0.41	0.08	0.20	0.01
Plume 13	13	60	20	-	0.54	0.04	0.1	0.03
Plume 14	14	340	200	-	0.58	0.00	0.20	0.05
Plume 15	15	<20	<10	-	0.78	0.10	0.0	0.04
Plume 16	16	20	<10	-	0.65	0.03	0.1	0.04
Plume 17	17	20	10	-	0.54	0.02	0.6	0.01
Plume 18	18	80	20	-	0.79	0.0	0.0	0.06
Plume 19	19	<20	10	-	0.52	0.0	0.0	0.02
Plume 20	20	600	120	-	0.84	0.0	0.0	0.03
Plume 21	21	1100	20	15	0.93	0.05	0.0	0.03
Plume 22	22	60	< 5	50	0.26	0.05	0.0	0.09
Background E	G	400	< 5	90	0.30	0.08	0.0	0.03
Background F	H	30	< 5	< 5	0.26	0.06	0.0	0.03
	Mean	516	179		0.60	0.02	0.10	0.05

* colonies per 100/ml of sample
** mg per liter of sample

Table A-2

WATER QUALITY GRAB SAMPLE ANALYSIS
(as presented in Johns Pond Report)

Analyses of Water Receiving Groundwater Discharges from Domestic Septic Units, Natural Bogs, or Inflows to Johns Pond, Mashpee

Station	Volume Ranking	Coliform Count+ #/100 ml	Nutrient Content (mg/l) PO_4-P	NO_3+NO_2-N	NH_4-N
5	13	--	.003	.012	.0042
10	17	20	.002	.002	.0095
12	19	900	.001	.163	.0195
14	22	--	.010	.000	.0032
16	23	200	.003	.006	.0074
18	19	--	.002	.074	.0192
19c	9	1800	.001	.001	.001
28	24	10	.004	.003	.0099
32	7	--	.000	.003	.0112
42	21	--	.010	.355	.0342
42a	3	--	.002	.008	.0181
51	10	neg.	.001	.001	.002
52	4	90	.001	.002	.004
53	5	--	.002	.001	.002
58	12	--	.002	.002	.009
72	2	--	.002	.007	.0277
88	8	--	.004	.049	.0394
89	16	--	.002	.003	.0049
92	15	--	.002	.002	.0134
109 (Moody Pd.)	--	--	.000	.194	.0251
112a	1	--	.001	.020	.002
112b	1	--	.001	.050	.001
112c	1	--	.002	.249	.002
112d	1	--	.006	.305	.043
112e	1	--	.001	.079	.003
118	11	10	.007	.017	.0760
119	6	20	.002	.015	.0141
120	20	neg.	.000	.006	.0141
125	14	--	.003	.054	.0132
Muddy Pond	--	--	.009	.007	.088

Background Levels (Mean)			
North Pond (Deep Station)	.001	.002	.006
South Pond (Deep Station)	.001	.002	.003

+Bacterial analyses performed by Tim Hennigan Engineering, Inc. for the Town of Mashpee Public Health Department.

*Chemical analysis following EPA "Methods for Chemical Analysis of Water and Wastes," U.S. Environmental Protection Agency, Washington, D. C.

Table A-3
WATER QUALITY GRAB SAMPLE ANALYSIS LOCATIONS
(as presented in Otter Tail Lake Report)

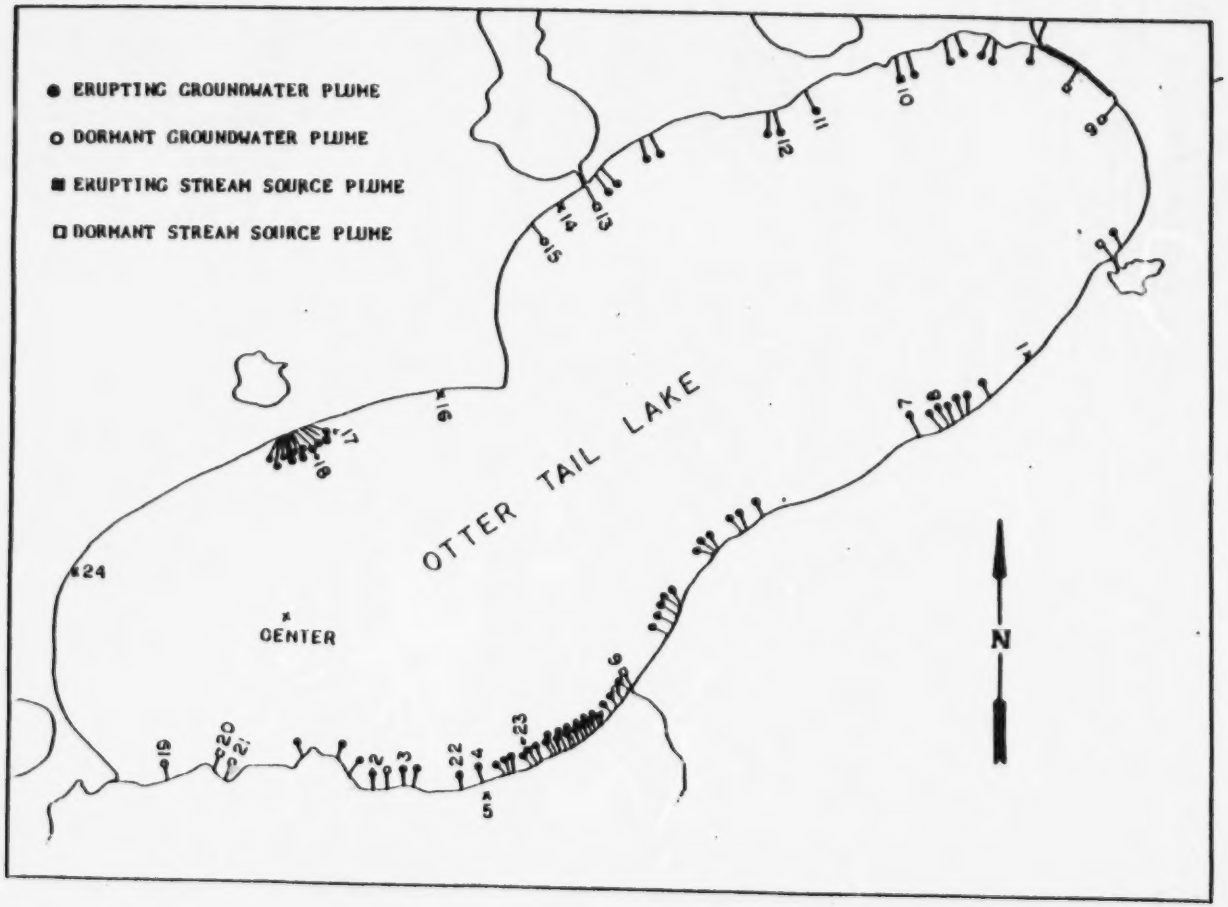


Table A-5
WATER QUALITY GRAB SAMPLE ANALYSIS
(as presented in Otter Tail Lake Report)

Sample* Number	Conductivity	TDS ppm	NO_2-N ppm	NO_3-N ppm	NI_3-N ppm	Organic N ppm	C1- ppm	Na ppm
1S-B	320	194	<.01	.02	<.03	.75	3	6.3
1G-B	430	285	<.01	3.38	<.03	.10	4	4.6
2S	340	218	.01	.01	.03	.80	4	6.2
2G	510	299	<.01	.01	.15	.35	2	3.1
3S	340	204	<.01	.02	<.03	.72	4	6.7
3G	620	413	<.01	.03	<.03	.80	2	7.0
4S	325	171	<.01	.01	<.03	.98	4	7.0
4G	640	419	<.01	.04	1.19	1.21	7	13
5S	590	365	<.01	.01	.68	1.22	7	10
6S	-	223	<.01	.02	.03	.74	4	7.6
7S	340	190	<.01	.07	<.03	.47	3	6.5
7G	525	323	<.01	.01	.12	.38	8	4.6
8S	340	193	<.01	.12	<.03	.64	4	6.9
8G	475	300	<.01	7.18	<.03	.10	20	5.0
9S	320	193	<.01	.05	<.03	.98	3	6.7
10S	330	230	<.01	.03	<.03	1.30	3	7.6
10G	855	550	<.01	.04	7.50	2.00	4	6.8
11S	320	195	<.01	.04	<.03	.75	4	7.4
11G	400	242	<.01	<.01	.28	.30	4	9.3
12S	325	197	<.01	.04	<.03	.90	3	7.4
12G	490	339	<.01	.03	.46	1.19	4	4.0
13S	400	256	<.01	.02	<.03	1.25	3	6.7
14S-B	325	181	<.01	.06	<.03	.88	4	7.2
14G-B	920	500	<.01	.02	11.5	.10	6	8.0
15S	340	185	.01	.08	<.03	.65	4	7.1
15G	585	322	<.01	.03	.40	.55	6	5.3
14S-B	325	171	<.01	.02	<.03	.62	3	7.2
16G-B	560	322	<.01	.01	.52	.09	2	5.5
17S	340	198	<.01	.02	<.03	.67	4	7.0
17G	600	381	<.01	.04	1.68	1.80	3	6.3
18S	150	199	<.01	.02	.06	.80	4	7.2
18G	480	309	<.01	.02	.28	.68	7	6.3
19S	325	191	<.01	.02	<.03	.53	4	7.1
19G	570	351	<.01	.01	.25	.02	4	3.9

Table A-6
WATER QUALITY GRAB SAMPLE ANALYSIS
(as presented in Otter Tail Lake Report)

Sample* Number	Conductivity	TDS ppm	NO_2-N ppm	NO_3-N ppm	NI_3-N ppm	Organic N ppm	C1- ppm	Na ppm
20S	340	190	<.01	.02	<.03	.51	4	6.5
20G	480	281	<.01	.01	.03	.19	2	3.0
21S	370	203	<.01	.02	<.03	.69	4	6.6
21G	525	299	<.01	.01	.03	.13	4	4.2
22S	285	187	<.01	.02	<.03	.89	4	7.0
22G	470	292	<.01	.03	.18	.62	4	8.2
23S	310	192	<.01	.02	<.03	.66	4	7.0
23G	570	337	<.01	.02	1.18	.67	4	9.3
24S	330	168	<.01	.01	<.03	.76	4	7.4
24G	1620	667	.0	.03	.35	.29	266	154

*s = surface water water sample; g = groundwater sample; B = background sample

Table A-5

WATER QUALITY GRAB SAMPLE ANALYSIS LOCATIONS
(as presented in Crystal Lake Report)

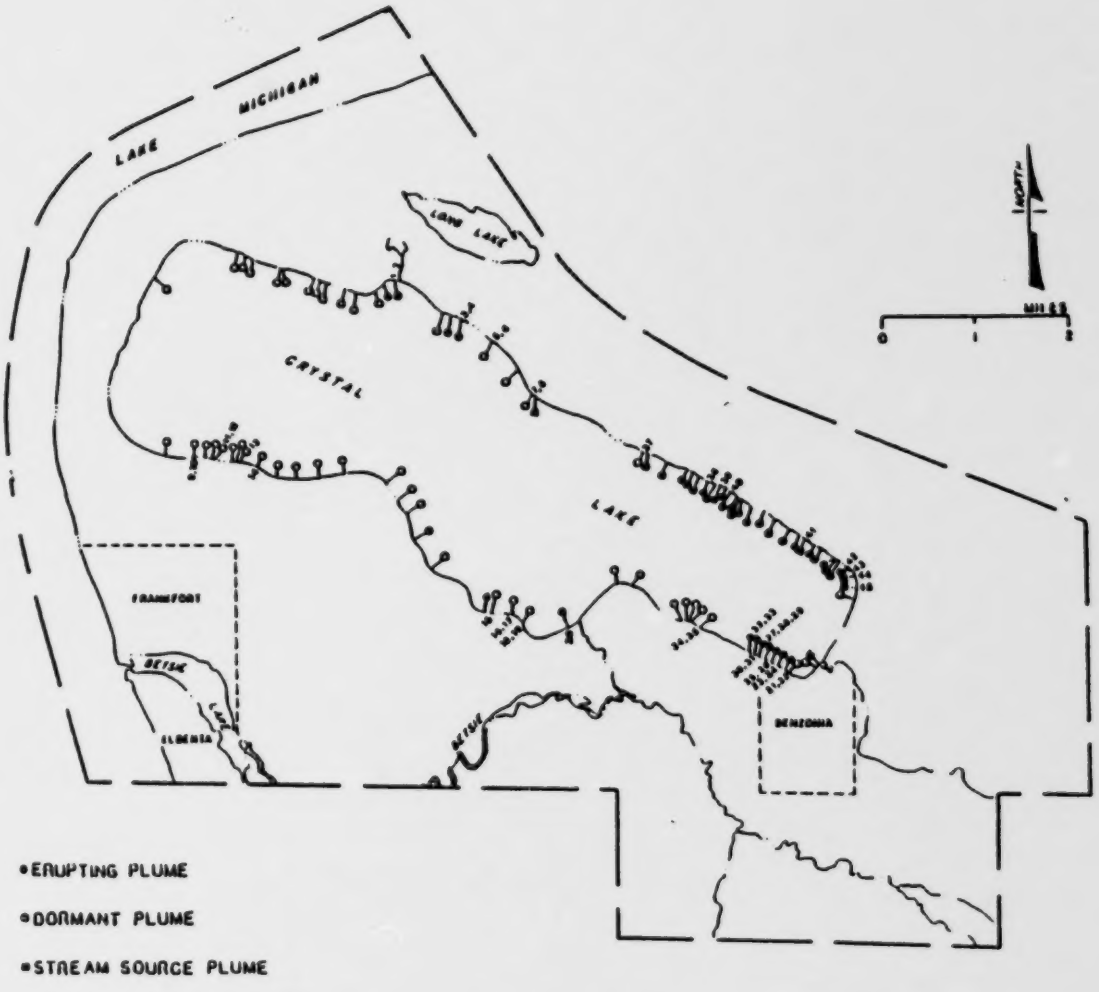


Table A-6

WATER QUALITY GRAB SAMPLE ANALYSIS

(as presented in Crystal Lake Report)

Nutrient analyses of surface (S) and groundwater (G) samples taken in the vicinity of wastewater leachate plumes observed on the Crystal Lake shoreline.

Sample Number		Cond.	Concentration (ppm - mg/l) PO_4-P	TP	NH_4-N	NO_3-N	Ratio ΔC	ΔP	ΔN	Breakthrough P	N
1	S	300	.0008	.003	.004	.043					
2	G	525	.004	.009	.263	.003	125	.005	.23	.5%	4%
3	S	250	.0005	.002	.003	.011					
4	G	490	.017	.020	.034	.277	90	.016	.28	.8%	6%
5	S	270	.021	.022	.094	.062					
6	G	460	-	.029	.195	.890	60	.025	1.06	2%	35%
7	S	410	.002	.003	.005	.297					
8	G	280	.0005	.001	.0003	.847					
9	S	315	.008	.004	.001	.060					
10	G	383	.0005	.008	.009	.224					
11	S	410	.002	.003	.004	.048					
12	G	403	.006	.022	.026	.269					
13	S	365	.0009	.002	.006	.128					
14	S	390	.001	.003	.004	.084					
15	bkgs	385	.001	.004	.003	.060					
16	S	380	.002	.003	.004	.045					
17	G	600	.009	.020	.004	1.808	200	.016	1.78	.4%	18%
18	S	382	.004	.004	.004	.048					
19	G	438	.006	.006	.002	.220	38	.002	.19	.3%	10%
20	S	412	.001	.003	.0003	.029					
21	S	384	.003	.004	.008	.024					
22	G	555	.011	.024	3.773	.016	155	.020	3.76	.7%	49%
23	S	416	.002	.004	.024	.026					
24	G	368	.003	.012	.056	.083					
25	S	450	.002	.004	.013	.239					
26	G	636	.010	.020	.025	3.144	236	.02	3.11	.4%	21%
27	S	390	.001	.005	.005	.134					

Table A-6 (continued)

WATER QUALITY GRAB SAMPLE ANALYSIS

(as presented in Crystal Lake Report)

Sample Number		Cond.	Concentration (ppm - mg/l) PO_4-P	TP	NH_4-N	NO_3-N	Ratio ΔC	ΔP	ΔN	Breakthrough P	N
28	S	430	.002	.005	.008	.194					
29	G	610	.043	.057	.020	.950	210	.053	.97	1.4%	9.7%
30	S	420	.002	.003	.010	.171					
31	G	610	.007	.010	.012	1.523	210	.006	1.52	.2%	14.5%
32	S	420	.002	.003	.013	.111					
33	G	490	.009	.012	.125	.029	90	.008	.122	.4%	3%
34	S	400	.002	.004	.078	.048					
35	G	430	.004	.011	.069	.011	30	.006	.05	1%	3%
36	S	360	.004	.011	.032	1.385					
37	S	378	.003	.004	.014	.056					
38	S	403	.002	.004	.009	.391					
39	S	420	.002	.004	.005	.436					
40	S	400	.003	.004	.006	.564					
41	lost in transit										
42	S	410	-	.607	.287	-					
43	S	368	-	.012	.484	-					
44	S	420	-	.024	.167	-					
45	S	270	-	.025	.246	-					
Background concentration		400		.004	.003	.030					
Local effluent							+400	+8	+20		

Table A-7

WATER QUALITY GRAB SAMPLE ANALYSIS
(as presented in ERA Study)

Analysis of Water Sample Taken at Moultonborough Bay, May 26, 1977.

Septic Leachate Detector Peaks.

Station	Inorganic Phosphate-Phosphorus (PO_4-P) in ppm	Total Phosphorus (P) in ppm	Nitrate and Nitrite-Nitrogen ($NO_3 + NO_2$) - N in ppm	Ammonia-Nitrogen (NH_4-N) in ppm	Specific Conductance in micro mhos per cm
(Background 1)	.00	.0016	.0036	.0045	32.2
(Background 2)	.0006	.0028	.0213	.0080	42.2
48	.00	.0034	.0133	.0049	41.0
53	.0019	.0053	.0102	.0099	39.4
56	.0006	.0056	.0126	.007	40.2
61	.0019	.0056	.0069	.0060	40.9
63	.0022	.0059	.0144	.0048	41.8
65	.0016	.0037	.0087	.0027	41.9
65A	.0006	.0034	.0109	.0042	37.6
75	.0009	.0031	.0119	.0060	36.0
76	.0078	.0233	.0127	.0084	38.2
76B	.0019	.0062	.0120	.0057	42.8
84	.0009	.0078	.0223	.0043	37.9

Table A-8

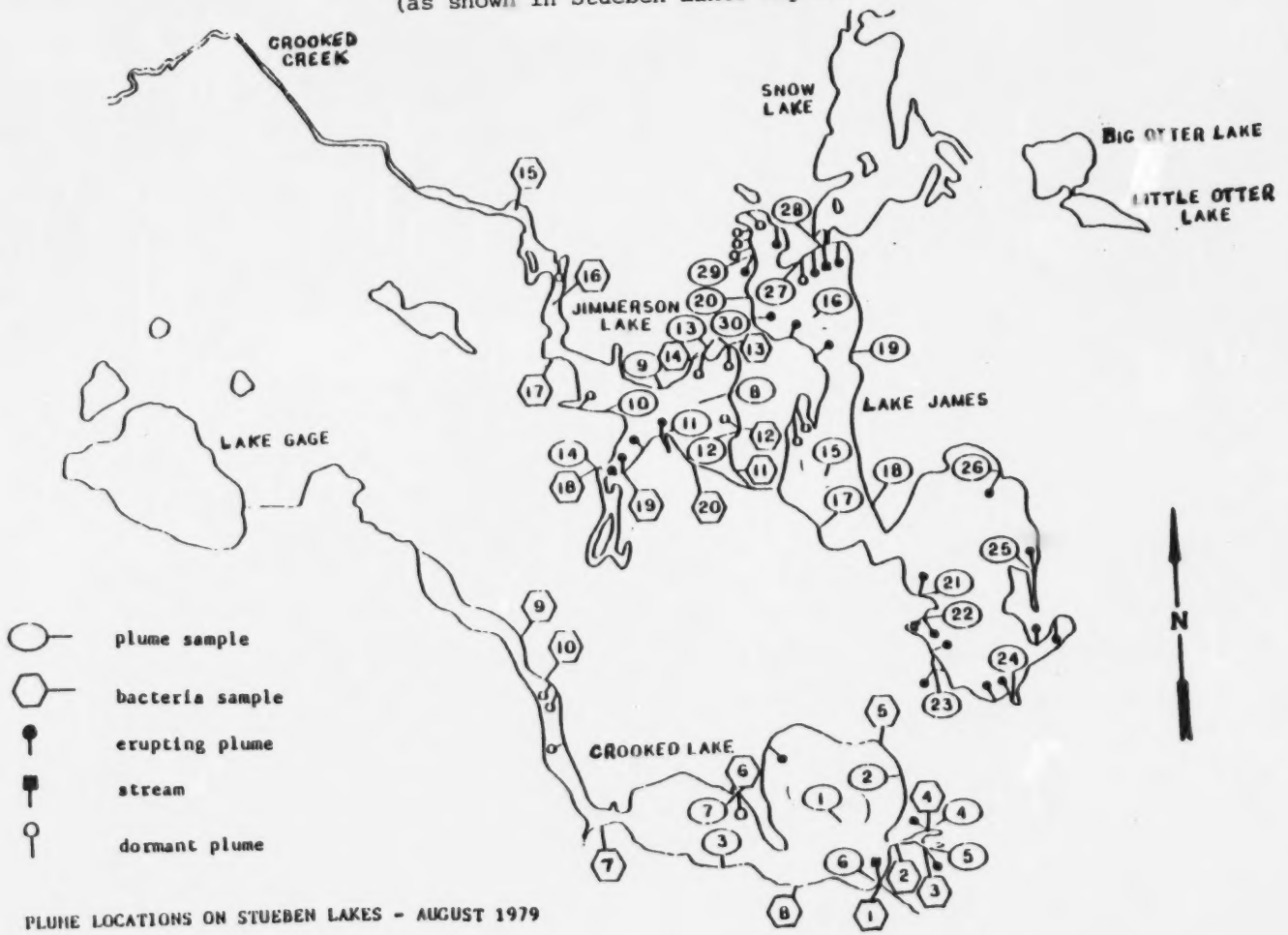
WATER QUALITY GRAB SAMPLE ANALYSIS

MOULTONBOROUGH BAY WATER SAMPLES, AUGUST 24, 1977.
Concentrations are given in milligrams per liter (mg/l-ppm), except with Conductance. Septic Leachate Detector Peaks.

	Orthophosphate (PO_4-P)	Total Phosphorus (TP)	Nitrate Nitrogen (NO_3-N)	Ammonia Nitrogen (NH_4-N)	Conductance umhos
Background (landing)	..0037	.0081	.0035	.0133	40.1
Station 64	.0037	.0133	.0032	.0113	46.4
Station 65B	.0037	.0205	.0032	.0168	44.2
Station 68	.0037	.0096	.0029	.0123	42.4
Station 70	.0037	.0112	.0029	.0157	43.5
Station 73-70	.0040	.0109	.0034	.0196	46.4
Station 75	.0037	.0090	.0043	.0174	42.7
Station 76 (1)	.0037	.0192	.0028	.0168	44.6
Station 76 (2)	.0037	.0171	.0036	.0165	43.6
Station 81	.0037	.0068	.0158	.0213	45.0
Station 84	.0037	.0081	.0041	.0154	46.5

Table A-9

WATER QUALITY SAMPLE GRAB ANALYSIS LOCATIONS
(as shown in Stueben Lakes Report)



PLUME LOCATIONS ON STUEBEN LAKES - AUGUST 1979

Exhibit A-10

WATER QUALITY GRAB SAMPLE ANALYSIS
(as shown in Stueben Lakes Report)

Sample* Numbers	TDS ppm	NO_2-N ppm	NO_3-N ppm	NH_3-N ppm	Organic N ppm	Cl- ppm	Na ppm
Crooked Lake							
1S	343	<.01	.01	<.03	.57	76	63
2S	324	<.01	.02	<.03	.68	76	43
2G	717	<.01	.01	2.08	10.4	133	175
3S	327	<.01	.02	<.03	.72	76	41
3G	744	<.01	.05	1.70	1.90	183	59
4S	486	.01	.14	.04	.96	95	60
5S	444	.02	.67	.08	.18	72	43
5G	1089	<.01	.01	.18	1.07	336	165
6S	421	<.01	.39	<.03	.87	88	60
6G	570	<.01	.04	1.78	1.82	66	31
7S	334	<.01	.02	<.03	.68	77	44
7G	459	<.01	.02	2.75	24.4	75	37
Jimmerson Lake							
3S	244	<.01	.02	<.03	.50	30	13
9S	263	<.01	.01	<.03	.74	30	16
9G	573	<.01	.07	22.2	10.3	6	5
10S	260	<.01	.01	<.03	.68	30	17
10G	378	<.01	<.01	1.75	2.95	12	7
11S	267	<.01	.01	<.03	.62	31	17
11G	325	<.01	<.01	<.03	.36	2	5
12S	251	<.01	.01	<.03	.60	32	17
12G	694	<.01	.01	10.8	1.20	22	12
13S	269	<.01	<.01	< .03	.68	30	17
13G	359	<.01	.30	.76	.49	8	4
14S	263	<.01	.01	< .03	.74	28	13
14G	368	<.01	.02	1.90	3.60	9	5

* = surface water sample; G = groundwater sample

Exhibit A-10 (continued)

WATER QUALITY GRAB SAMPLE ANALYSIS
(as shown in Stueben Lakes Report)

Sample* Numbers	TDS ppm	NO_2-N ppm	NO_3-N ppm	NH_3-N ppm	Organic N PPM	Cl- ppm	Na ppm
James Lake							
15S	262	<.01	.01	<.03	.56	32	18
16S	270	<.01	.01	<.03	1.43	61	18
17S	278	<.01	.02	<.03	.50	31	17
17G	555	<.01	.08	26.0	2.00	17	10
16S	257	<.01	.02	<.03	.70	31	17
18G	273	<.01	.01	.03	3.30	27	17
19S	254	<.01	.01	<.03	1.60	52	17
19G	408	<.01	<.01	.37	18.3	23	7
20S	243	<.01	.02	<.03	1.38	56	18
20G	353	<.01	<.01	<.03	3.60	3	4
21S	266	<.01	.01	<.03	.60	30	17
21G	289	<.01	.01	.14	15.4	3	15
22S	261	<.01	.02	<.03	.87	28	15
22G	468	<.01	<.01	14.0	10.5	26	15
23S	257	<.01	.02	<.03	.37	30	18
24S	304	.01	<.01	.05	1.35	30	17
24G	648	.04	.50	30.0	17.5	15	14
25S	259	.01	.01	<.03	.80	31	17
25G	453	.01	.01	2.30	5.00	45	26
26S	328	.01	.01	<.03	.38	49	29
26G	700	.01	<.01	62.0	68.5	26	18
27S	259	.01	.01	.03	1.15	57	19
27G	286	.01	.01	.65	3.45	49	17
28S	286	.01	.01	<.03	1.32	56	22
29S	257	.01	.01	<.03	1.34	63	18
30S	264	.01	.01	<.03	1.37	67	19
30G	412	.03	.41	<.03	1.25	73	6

*S = surface water sample; G = groundwater sample

Table A-12

WATER QUALITY GRAB SAMPLE ANALYSIS
(as presented in Squam Lake Report)

Analysis of Water Samples taken at Squam Lake, June 22, 1977

Station	Inorganic Phosphate-Phosphorus (PO_4-P) in ppm	Total Phosphorus (P) in ppm	Nitrate-Nitrogen (NO_3 - N) in ppm	Ammonia-Nitrogen (NH_4-N) in ppm	Specific Conductance in micro mhos per cm
			Cotton Cove		
Background	.0003	.0053	.0008	.0024	41.2
20	.0008	.0071	.0013	.0020	41.1
24	.0003	.0180	.0013	.0020	38.9
36	.0005	.0065	.0013	.0024	41.0
			Piper Cove		
Background	.0008	.0068	.0013	.0056	41.2
3	.0006	.0111	.0017	.0085	43.2
5	.0008	.0115	.0024	.0283	50.2
8	.0010	.0174	.0013	.0157	46.9
8A	.0090	.3519	.0389	.1898	230.0
13	.0003	.0074	.0014	.0028	40.2

Table A-12 (continued)
WATER QUALITY GRAB SAMPLE ANALYSIS
(as presented in Squam Lake)

Analysis of Water Samples Taken at Squam Lake, September, 14, 1977

Station	Inorganic Phosphate-Phosphorus (PO_4-P) in ppm	Total Phosphorus (P) in ppm	Nitrate-Nitrogen (NO_3-N) in ppm	Ammonia-Nitrogen (NH_4-N) in ppm)
		Cotton Cove		
Background	.0025	.0056	.0095	.0057
7	.0009	.0121	.0592	.0069
32	.0028	.0081	.2023	.0070
39	.0028	.0071	.0162	.0066
42	.0025	.0090	.0132	.0060
		Piper Cove		
Background	.0022	.0065	.0090	.0073
5	.0028	.0112	.0517	.0255
6	.0022	.0084	.0441	.0295
7	.0028	.0105	.0273	.2092
8B	.0025	.0105	.0090	.0200

Table A-13

Lake Attitash Complete Sample

BACKGROUND SAMPLE #	TOTAL COLIFORM *	FECAL COLIFORM *	TOTAL (Kjel.) N x100 ppm	NH3-N x100 ppm	NO3-N X100 ppm	TOTAL P x100 ppm
A	20	10	71	2	0	4
B	120	10	304	190	430	540
C	20	10	64	1	0	1
D	80	30	77	2	1	6
E			59	0	0	3
F	50	10	83	3	70	4
G	400	5	30	8	0	3
H	30	5	26	6	0	3
MEAN Log10	102.9	15.0	129.0	48.8	107.8	137.8
STDE Log10	136.0	10.0	116.8	94.2	214.8	268.2
PLUMES						
1	3800	1500	81	3	0	20
2	180	110	73	0	0	17
3	360	180	82	1	0	13
4	300	140	67	0	0	8
5	300	140	70	2	0	7
6	80	40	65	1	0	3
7	2400	800	72	1	0	4
8	3000	1400	56	1	0	3
9	240	40	65	2	0	3
10	200	100	105	0	10	9
11	400	20	67	1	100	4
12	300	80	48	0	10	4
12A	400	20				
12B	20	10	41	8	20	1
13	60	20	54	4	10	3
14	340	200	58	0	20	5
15	20	10	78	10	0	4
16	20	10	65	3	10	4
17	20	10	54	2	60	1
18	80	20	79	0	0	6
19	20	10	52	0	0	2
20	600	120	84	0	0	3
21	1100	20	93	5	0	3
22	60	5	26	5	0	9
MEAN Log10	395.8	153.1	65.0	2.3	12.0	4.3
STDE Log10	1005.1	333.4	17.9	2.8	25.0	2.4
t	0.9	1.8	-0.9	-0.9	-0.8	-0.9
v	25.6	23.2	7.1	7.0	7.0	7.0
Pr						

Table A-14

Lake Attitash Corrected Sample

BACKGROUND SAMPLE #	TOTAL COLIFORM *	FECAL COLIFORM *	TOTAL (Kjel.) N x100 ppm	NH3-N x100 ppm	NO3-N X100 ppm	TOTAL P x100 ppm
A	20	10	71	2	0	4
C	20	10	64	1	0	1
D	80	30	77	2	1	6
E			59	0	0	3
F	50	10	83	3	70	4
G	400	5	30	8	0	3
H	30	5	26	6	0	3
MEAN Log10	100.0	16.7	70.7	1.7	0.3	3.7
STDE Log10	148.7	11.5	6.5	0.6	0.6	2.5
PLUMES						
4	300	140	67	0	0	8
5	300	140	70	2	0	7
6	80	40	65	1	0	3
7	2400	800	72	1	0	4
8	3000	1400	56	1	0	3
9	240	40	65	2	0	3
10	200	100	105	0	10	9
11	400	20	67	1	100	4
13	60	20	54	4	10	3
14	340	200	58	0	20	5
15	20	10	78	10	0	4
16	20	10	65	3	10	4
17	20	10	54	2	60	1
18	80	20	79	0	0	6
19	20	10	52	0	0	2
20	600	120	84	0	0	3
21	1100	20	93	5	0	3
22	60	5	26	5	0	9
MEAN Log10	513.3	172.5	67.2	2.1	11.7	4.5
STDE Log10	845.8	357.5	17.4	2.6	26.4	2.4
t	2.0	1.8	-0.6	0.6	1.8	0.5
v	19.7	17.2	19.2	22.9	17.1	7.8
Pr						

Table A-15

Johns Pond Surface Water Samples

BACKGROUND			
SAMPLE #	PO4-P x1000 ppm	NO3+NO2-N x1000 ppm	NH3-N x10000 ppm
NORTH POND	1	2	60
SOUTH POND	1	2	30
MEAN	1.0	2.0	45.0
STDEV	0.0	0.0	21.2
PLUMES			
5	3	12	42
10	2	2	95
12	1	163	195
14	10	0	32
16	3	6	74
18	2	74	192
19c	1	1	10
28	4	3	99
32	0	3	112
42	10	355	342
42a	2	8	181
51	1	1	20
52	1	2	40
53	2	1	20
58	2	2	90
72	2	7	277
88	4	49	394
89	2	3	49
92	2	2	134
109	0	194	251
112a	1	20	20
112b	1	50	10
112c	2	249	20
112d	6	305	430
112e	1	79	30
118	7	17	760
119	2	16	141
120	0	6	141
125	3	54	132
MEAN	2.7	58.1	149.4
STDEV	2.6	97.9	165.2
t	3.5	3.1	3.1
v	28.0	28.0	16.5
Pr	1%	1%	1%

Table A-16

OTTER TAIL LAKE Subsurface Water Samples

BACKGROUND SAMPLE #	COND.	TDS ppm	NO3-N x100 ppm	ORGANIC-N x100 ppm	Cl- ppm	Na x10 ppm
1	320	194	2	75	3	63
14	325	181	6	88	4	72
16	325	171	2	62	3	72
	323.3	182.0	3.3	75.0	3.3	69.0
	2.9	11.5	2.3	13.0	0.6	5.2
PLUMES						
2	340	218	1	80	4	62
3	340	204	2	72	4	67
4	325	171	1	98	4	70
6		223	2	74	4	76
7	340	190	7	47	3	65
8	340	193	12	64	4	69
9	320	193	5	98	3	67
10	330	230	3	130	3	76
11	320	195	4	75	4	74
12	325	197	4	90	3	74
13	400	256	2	125	3	67
15	340	185	8	65	4	71
17	340	198	2	67	4	70
18	350	199	2	80	4	72
19	325	191	2	53	4	71
20	340	190	2	51	4	65
21	370	203	2	69	4	66
22	285	187	2	89	4	70
23	330	192	2	66	4	70
MEAN	336.7	200.8	3.4	78.6	3.7	69.6
STDEV	23.1	19.2	2.8	22.4	0.5	3.8
t	2.3	2.4	0.1	0.4	1.2	0.2
v	18.9	4.0	3.0	4.2	2.4	2.4
Pr	4%	8%	93%	71%	36%	18%

Table A-17

CRYSTAL LAKE Surface Water Sample

BACKGROUND SAMPLE #	COND.	PO4-P x1000 ppm	TOTAL P x1000 ppm	NH3-N x1000 ppm	NO3-N x1000 ppm
15	385	1	4	3	60
MEAN	385.0	1.0	4.0	3.0	60.0
STDEV	0.0	0.0	0.0	0.0	0.0
PLUMES					
1	300	1	3	4	43
3	250	1	2	3	11
5	270	21	22	94	62
7	410	2	3	5	297
9	315	8	4	1	60
11	410	2	3	4	48
13	365	1	2	6	128
14	390	1	3	4	84
16	380	2	3	4	45
18	382	4	4	4	48
20	412	1	3	0	29
21	384	3	4	8	24
23	416	2	4	24	26
25	430	2	4	13	239
27	390	1	5	5	134
28	340	2	5	8	194
30	420	2	3	10	171
32	420	2	3	13	111
34	400	2	4	78	48
36	360	4	11	32	1385
37	378	3	4	14	56
38	403	2	4	9	391
39	420	2	4	5	436
40	400	3	4	6	564
42	410		607	287	
43	368		12	484	
44	420		24	167	
45	270		25	246	
MEAN	375.5	3.1	27.8	54.9	193.1
STDEV	50.5	4.1	113.7	111.9	293.0
t	-1.0	2.5	1.1	2.5	2.2
v	27.0	23	27.0	27.0	23
Pr	*	2%	28%	2%	4%

Table A-18

ERA STUDY - MAY 1977

Surface Water Samples

BACKGROUND					
SAMPLE #	PO4-4 10^4 ppm	TOTAL P 10^4 ppm	NO3+NO2-N 10^4 ppm	NH3-N 10^4 ppm	COND. x10
1	0	16	36	45	322
2	6	28	213	80	422
MEAN	3.0	22.0	124.5	62.5	372.0
STDEV	4.2	8.5	125.2	24.7	70.7
PLUMES					
48	0	34	133	49	410
53	19	53	102	99	394
56	6	56	126	70	402
61	19	56	69	60	409
63	22	59	144	48	418
65	16	37	87	27	419
65A	6	34	109	42	376
75	9	31	119	60	360
76	78	233	127	84	382
76B	19	62	121	57	428
84	9	78	223	43	379
MEAN	18.5	66.6	123.6	58.1	397.9
STDEV	21.0	57.1	39.3	20.3	21.4
t	2.2	3.1	0.0	-0.3	0.6
v	10.0	10.9	1.0	1.2	1.0
Pr	6%	2%	100%	*	66%

Table A-19
ERA STUDY AUGUST 1977
Surface Water Samples

BACKGROUND					
SAMPLE #	PO4-4 10^4 ppm	TOTAL P 10^4 ppm	NO3+NO2-N 10^4 ppm	NH3-N 10^4 ppm	COND. 10
1	37	81	35	133	401
MEAN	37.0	81.0	35.0	133.0	401.0
STDEV	0.0	0.0	0.0	0.0	0.0
PLUMES					
64	37	133	32	113	464
65B	37	205	32	168	442
68	37	96	29	123	424
70	37	112	29	157	435
73-70	40	109	34	196	464
75	37	90	43	174	427
76 (1)	37	192	28	168	446
76 (2)	37	171	36	165	436
81	37	68	158	213	450
84	37	81	41	154	465
MEAN	37.3	125.7	46.2	163.1	445.3
STDEV	0.9	48.0	39.6	29.8	15.3
t	1.0	4.0	1.2	4.3	12.3
v	9.0	9.0	9.0	9.0	9.0
Pr	35%	1%	27%	1%	0%

Table A-20

STUEBEN LAKES/CROOKED LAKE

Surface Water Samples

BACKGROUND					
SAMPLE #	TDS ppm	NO3-N 10^2 ppm	TOTAL N 10^2 ppm	Cl ppm	Na ppm
1	343	1	57	76	43
MEAN	343.0	1.0	57.0	76.0	43.0
STDEV	0.0	0.0	0.0	0.0	0.0
PLUMES					
2	324	2	68	76	43
3	327	2	72	76	41
4	486	14	96	95	60
5	444	67	18	72	43
6	421	89	87	88	60
7	334	2	68	77	44
MEAN	389.3	29.3	68.2	80.7	48.5
STDEV	70.1	38.6	27.1	8.8	9.0
t	1.6	3.1	1.8	2.2	2.6
v	5.0	5.0	5.0	5.0	5.0
Pr	17%	3%	14%	8%	5%

Table A-21

STUEBEN LAKES/JIMMERSON LAKE

Surface Water Samples

BACKGROUND SAMPLE #	TDS ppm	NO3-N 10^2 ppm	N 10^2 ppm	Cl ppm	Na ppm
8	244	2	50	30	13
MEAN	244.0	2.0	50.0	30.0	13.0
STDEV	0.0	0.0	0.0	0.0	0.0
PLUMES					
9	263	1	74	30	16
10	260	1	68	30	17
11	267	1	62	31	17
12	251	1	60	32	17
13	269	1	68	30	17
14	263	1	74	28	15
MEAN	262.2	1.0	67.7	30.2	16.5
STDEV	6.3	0.0	5.9	1.3	0.8
t	7.0	#DIV/0!	12.8	0.6	17.8
v	5.0	5.0	5.0	5.0	5.0
Pr	1%	*	0%	55%	0%

Table A-22

STUEBEN LAKES/JAMES LAKE

Surface Water Samples

SAMPLE #	TDS ppm	NO3-N 10^2 ppm	N 10^2 ppm	Cl ppm	Na ppm
BACKGROUND					
15	262	1	56	32	18
16	270	1	148	61	18
MEAN	266.0	1.0	102.0	46.5	18.0
STDEV	5.7	0.0	65.1	20.5	0.0
PLUMES					
17	278	2	50	31	17
18	257	2	70	31	17
19	254	1	160	52	17
20	243	2	138	56	18
21	266	1	60	30	17
22	261	2	87	28	15
23	257	2	37	30	18
24	304	1	185	30	17
25	259	1	80	31	17
26	328	1	88	49	29
27	259	1	115	57	19
28	286	1	132	56	22
29	257	1	134	63	18
30	264	3	137	67	19
MEAN	269.5	1.5	105.2	43.6	18.6
STDEV	22.7	0.7	44.2	14.6	3.4
t	0.5	3.3	0.1	-0.2	0.7
v	7.7	13.0	1.2	1.2	13.0
Pr	64%	1%	94%	*	50%

Table A-23
SQUAM LAKE - June 1977
Surface Water Samples

SAMPLE #	PO4-P 10^4 ppm	TOTAL P 10^4 ppm	NO3+NO2-N 10^4 ppm	NH3-N 10^4 ppm	COND. 10 ppm
BACKGROUND					
1	3	53	8	24	412
2	8	68	13	56	412
	5.5	60.5	10.5	40.0	412.0
	3.5	10.6	3.5	22.6	0.0
PLUMES					
20	8	71	13	20	411
24	3	180	13	20	389
36	5	65	13	24	410
3	6	111	17	85	432
5	8	115	24	283	502
8	10	174	13	157	469
8A	90	3519	389	1898	2300
13	3	74	14	28	402
MEAN	16.6	538.6	62.0	314.4	664.4
STDEV	29.8	1205.1	132.2	646.5	662.0
t	1.0	1.7	1.6	1.8	1.6
v	7.6	7.0	7.1	7.1	7.0
Pr	36%	14%	16%	12%	16%

Table A-24
SQUAM LAKE - Sept 1977
Surface Water Samples

SAMPLE #	PO4-P 10^4 ppm	TOTAL P 10^4 ppm	NO3+NO2-N 10^4 ppm	NH3-N 10^4 ppm
BACKGROUND				
1	25	56	95	57
2	22	65	90	73
	23.5	60.5	92.5	65.0
	2.1	6.4	3.5	11.3
PLUMES				
7	9	121	592	69
32	28	81	2023	70
39	28	71	162	66
42	25	90	132	60
5 (3)	28	112	517	255
6 (6)	22	84	441	295
7 (5)	28	105	273	2092
8B (4)	25	105	90	200
MEAN	24.1	96.1	528.8	388.4
STDEV	6.5	17.2	631.8	694.8
t	0.2	6.5	2.9	2.0
v	6.3	4.1	7.0	7.0
Pr	85%	1%	3%	9%

Table A-25

OTTER TAIL LAKE

Groundwater Samples

SAMPLE #	COND.	TDS ppm	NO3-N x100 ppm	ORGANIC-N x100 ppm	Cl- ppm	Na x10 ppm
BACKGROUND						
1	430	285	338	10	4	46
14	920	500	2	10	6	80
16	560	322	1	9	2	55
MEAN	636.7	369.0	113.7	9.7	4.0	60.3
STDEV	253.8	114.9	194.3	0.6	2.0	17.6
PLUMES						
2	510	299	1	35	2	31
3	620	413	3	80	2	70
4	640	419	4	121	7	130
7	525	323	1	38	8	-46
8	475	300	718	10	20	50
10	855	550	4	200	4	68
11	400	242	1	30	4	93
12	490	339	3	119	4	40
15	585	322	3	55	6	53
17	600	383	4	180	3	63
18	480	309	2	68	2	63
19	570	351	1	2	4	39
20	480	281	1	19	2	30
21	525	299	3	13	4	42
22	470	292	3	62	4	82
23	570	337	2	67	4	93
MEAN	549.7	341.2	47.1	68.7	5.0	62.1
STDEV	103.7	72.8	178.9	59.0	4.4	27.0
t	-0.6	-0.4	-0.6	4.2	0.6	0.1
v	2.1	2.3	2.6	15.0	5.9	3.8
Pr	*	*	*	1%	58%	93%

Table A-26

CRYSTAL LAKE

Groundwater Samples

BACKGROUND					
SAMPLE #	COND.	PO4-P x1000 ppm	TOTAL P x1000 ppm	NH3-N x1000 ppm	NO3-N x1000 ppm
	400		4	3	60
MEAN	400.0	#DIV/0!	4.0	3.0	60.0
STDEV	0.0	0.0	0.0	0.0	0.0
PLUMES					
2	525	4	9	263	3
4	490	17	20	34	277
6	460		29	195	890
8	280	1	1	0	847
10	383	1	8	9	224
12	403	6	22	26	269
17	600	9	20	4	1808
19	438	6	6	2	220
22	555	11	24	3773	16
24	368	3	12	56	83
26	636	10	20	25	3144
29	610	43	57	20	950
31	610	7	10	12	1523
33	490	9	12	125	29
35	430	4	11	69	11
MEAN	485.2	9.4	17.4	307.5	686.3
STDEV	104.4	10.6	13.4	961.8	889.5
t	3.2	N/A	3.9	1.2	2.7
v	14.0		14.0	14.0	14
Pr	1%		1%	25%	2%

APPENDIX B

STATISTICAL METHODS

The goal of the statistical analysis performed on the data presented in Appendix A was to determine whether, based on field observations, it is reasonable to assume that the SEPD surveys accurately and consistently distinguished between contaminated and ambient water quality. To do this, the difference between the mean of background observations and the mean of plume observations were compared.

The significance of differences observed between the means was then tested using a students t-test. This test determines the probability of observing a difference in means as great or greater than those observed during the SEPD surveys if there is in fact no difference. In other words, the test determines if there is enough difference between the means, given the precision of the measurements, to assume that the samples were actually collected from two populations (i.e, water contaminated with septic tank effluent vs. background lake water). The precision of the measurement of the means is indicated by their standard errors. If the difference in the means is not large relative to the standard errors, the probability is high that the data observations reported do not represent two distinct populations, but rather are illustrative of the degree of variance expected when collecting the samples from a single population. Since the SEPD concept is based on the assumption that the concentration in the plume is not only different from but greater than the background concentration, a one tailed t-test has been used to estimate levels of significance.

The hypothesis and its test can be stated mathematically as follows. Let:

X_p = the population mean of SEPD plumes,

X_c = the population mean for background water,

x_i = the corresponding sample means, i = p, c,

n_i = the corresponding sample sizes, i = p, c,

$D = X_p - X_c$, the difference in the population means,

$d = x_p - x_c$, the sample estimate of D,

s_i^2 = sample estimate of the variance of the measurements for population i, i = p, c.

$s_i/\sqrt{n_i}$ = standard error of estimate of the means, i = p, c.

Then, we are testing the null hypothesis

$$H_o: D = 0$$

against the alternative

$$H_1: D > 0$$

If we let d represent any possible estimate of D, then the significance of our test of the null hypothesis can be written:

$Pr[d \geq t : D = 0]$ = the significance level, where t is the critical value of a normal variant for a given level of significance.

The test statistic is

$$d/[(s_p^{\,2}/n_p) + (s_c^{\,2}/n_c)]^{1/2}$$

and this is approximately distributed student t with v degrees of freedom,

$$v = A/B$$

where $A = [(s_p^{\,2}/n_p) + (s_c^{\,2}/n_c)]^2$ and

$$B = [(s_p^{\,2}/n_p)^2 (1/(n_p-1)) + (s_c^{\,2}/n_c)^2 (1/(n_c-1))]$$

In general, the maximum acceptable level of significance for data of this type is 5%. In other words, the procedure being evaluated is only considered acceptable if the probability of false finding a difference in pollution measurements is 5% or less, when in fact, there is no difference (false positives).

Before presenting the results of this analysis, it is important to point out some of its limitations. In several instances, the SEPD surveys reported only a single background sample. For simplicity, in these cases, it was assumed that the reported background levels are perfect (i.e., standard deviation equal to zero). This over simplification assumes not only that the sample was collected in the correct location, but that it is a definitive representation of the water quality. Thus, any analysis which indicates a significance level of 5% or less where this assumption has been made, is over-optimistic.

APPENDIX C

QUESTIONNAIRE AND RESPONSES

K-V ASSOCIATES, INC.
ANALYTICAL SYSTEMS

281 MAIN STREET · P.O. BOX 574 · FALMOUTH, MASSACHUSETTS 02541 · 617-540-0561

July 10, 1981

Ms. Patricia Deese
Urban Systems Research & Engineering, Inc.
36 Boylston Street
Cambridge, MA 02138

Re: Letters of June 10 and 15, 1981; septic snooper theory and function

Dear Pat:

Thank you for forwarding the sales material distributed by ENDECO. From your previous letter and discussion at your Cambridge office with colleagues, it became apparent that you were operating under two misimpressions:

1) That we were fully aware of the sales information distributed by ENDECO;

2) That we were using a "Septic Snooper" from ENDECO during services offered from 1979 through 1981.

Although two of the principals in the development of the "Septic Snooper" are at K-V Associates (W. Kerfoot and S. Skinner , both had left ENDECO in 1978 after the directors' decision to channel business activities towards the marine environment.) Contact with WAPORA, Inc allowed us to employ the prototype unit of the septic snooper at Crystal Lake, Michigan. Crystal Lake presented an almost ideal situation for a leachate detector since residential housing and septic system installation had been proceeding on porous sandy lake bed deposits with often substantial groundwater inflow rates. Subsequently, KVA paid for the first unfinished commercial "septic snooper" for use in winter surveys. The unit was not completed and required substantial modifications by our personnel to function properly as a septic leachate detector. The modified unit has been the principal unit used for septic leachate detection services during 1979 through spring 1981. In answering questions concerning the theory and operation of a leachate detector, we will concentrate attention to the equipment used in the past and not with regard to any future detector units. Please note also that ENDECO decided to sell a commercial septic leachate unit after our initial success in survey work. The unit was trademarked by ENDECO as a "Septic Snooper" and sold without consideration to any modifications made or used by K-V Associates.

The sales material currently used by ENDECO makes far clearer your questions of June 10. I had previously seen the Data Sheet No. 62 of June 21, 1977, but

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the undated handout entitled "A Descriptive Summary of the ENDECO Type 2100 Septic-Snooper System" which I had not seen previously has clearly been continuously updated. The reference to optimal lake levels probably refers to papers I presented in Wisconsin and Minnesota (AWRA Conference and University of Minnesota, respectively) in 1980 during which a representative of Swanson Engineering was present. The reference to future property development could refer to a Minnesota conference conducted during winter 1980-1981.

From my knowledge of septic leachate detector function, the claims that a septic snooper system application includes:

" -Assistance in determining optimum lake levels and other facets of in-lake management programs

-Help in planning future property development

-Identification of the direction and relative amplitude of groundwater inflows:

are not valid claims. The first two of these can be performed by combined leachate detection and groundwater flow measurement. By relating the frequency of discharges into the lake to prevailing groundwater flow patterns, and then adjusting the lake level relative to groundwater elevation, the lake waters can be made to predominately discharge towards the shore (i.e., exfiltrate) or maintain low flow rates conducive to proper soil adsorption field functioning.

The third claim, however, has no relevance to septic leachate detection. Although field documentation supports the relationship between a high probability of plume discharges in rapid groundwater infiltration regions along lake shorelines, a leachate detector cannot identify the direction and relative amplitude of groundwater inflows -- only a groundwater flowmeter can do this. In fact, using a leachate detector without independent groundwater flow information can result in serious misinterpretations of probable source and impacts.

I have attempted to answer your fairly extensive list of questions. Documentation is provided to specific references, conference proceedings, or other sources of information. Please note that while I must avoid questions of a proprietary nature, much of the information has been presented publicly. The notation of questions refers to your letter of June 10, 1981.

Sincerely,

Bill

William B. Kerfoot

WBK:phk
Enclosure

P.S. A copy of a consultant's report will be forwarded to you upon receiving approval from the consulting firm.

Bill

1. Theory

1.01 Yes, but with some important limitations. A septic leachate detector detects the presence of wastewater-related organics penetrating into lakewaters. This may be caused by a (1) hydraulic overflow (traditional failure) of the system and surface runoff or by (2) the movement of a subsurface plume of poorly-treated leachate from a soil absorption field through porous soils into the lake through bottom sediments. If the products of the leachfield do not flow towards the lake body, regardless of the condition of functioning of the septic system, the system cannot be evaluated by a shoreline survey.

1.02 The fluorescing compounds are generally considered to be indicators of contamination. Previous analysis of the whiteners have not as yet shown a cause for concern (Ganz, et. al., 1975; Keplinger, et. al., 1975). Some caution is needed because the class of aromatic compounds common to fluorescence comprise some compounds of potential biogenic effect. The principle contaminants of concern have been (a) pathogenic bacteria and (b) nutrients, particularly phosphorus.

1.03 Domestic wastewaters contain a variety of compounds which fluoresce within the range of a septic leachate detector (excitation: 340-370 nm):

a) Fluorescent whitening agents (FWA's)-sulfonated stilbene class*

DASC - 3	BSB	SNO - 1	SK
DASC - 4	NTS - 1	SOF	

(Ganz, et. al., 1975 a and b; and Gold, 1975)

b) Natural products which include:

Quinolines	Tryptophan derivatives
Phenols	Kynurenine
Catechols	Aromatic amino acids (other)

1.04 Fluorescent whitening agents are used as common additives to most commercial detergents and many water softeners. The commercial varieties observed in wastewaters often reflect the availability of brands at local distributors. A sample of secondarily-treated effluent or equivalent

* Official FWA designations which have been adopted by the ASTM

quality obtained at a local treatment plant often reveals the dominant FWA's to be anticipated in on-site wastewater systems. The natural products are common to all septic tank - soil absorption systems receiving human urine and feces.

With seasonal residences, plumes have been observed from dry wells connected to sinks even though chemical toilets were in use.

Documented concentrations of FWA found in domestic eastewater range from .494 - .043 (Zinkernagel, 1975), .495 - .107 (Ganz, et. al., 1975 a) Natural product concentrations are more stable than the fluorescent agents of commercial agents.

1.05 See following references:

Ganz, et. al., 1975 a
Ganz, et. al., 1975 b
Anders, 1975
Gold, 1975

1.06. Two principal mechanisms assist in removal of normal fluorescing compounds from septic systems:

1. Adsorption to solids
2. Biodegradation (Guglielmetti, 1975; Ganz, et. al., 1975 a)

1.07 Yes. In a properly functioning SAS, maintaining a suitable aerooic environment and soil adsorption, pathogen bacteria are physically filtered and attenuate rapidly. In addition, phosphorus is readily adsorbed by Fe or Ca based precipitation reactions.

1.08 Two types of commonly-encountered subsurface failures involve (1) septic absorption systems installed in coarse sand or gravel, frangipan underlain with fractured bedrock, solution channeled limestone or dolomite, with high rates of groundwater flow or (2) septic absorption systems in high groundwater conditions, organic deposits and moderate to rapid groundwater flow conditions.

In the case of coarsely textured materials, wastewater may have a short residence time before entering groundwater and emerging at the shoreline. Both filtering capacity and adsorptive area are severely limited under such conditions.

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1.09 The movement of bacteria in coarsely-textured substrates is well-documented, particularly for dolomites and limestones. Under low redox conditions, which retard the biodegradation of FWA's and natural fluorescent products, phosphorus becomes mobile as ferric (Fe^{+3}) changes to the soluble ferrous species (Fe^{+2}) (KVA, 1981).

1.10 The fluorescing compounds undergo

1. dispersion
2. photo-oxidation
3. biodegradation
4. adsorption

Yes and no. It depends upon the texture of the substrate and the season. a) With fractured bedrock, both bacteria and phosphorus behave conservatively within the time frame of dispersion. Reduction to 1/50 of original concentration is common. Where fine-textured sandy beaches may exist, bacteria may be effectively removed and phosphorus absorbed through thick mats of vegetation despite the continued presence of fluorescent indicators. (EPA, 1979) b) As shown with Ottertail Lake (Kerfoot, 1980) under winter conditions, however, phosphorus discharges occur without vegetative removal.

1.11 Since your statement of current scope of work is to evaluate the Septic Snooper manufactured by Environmental Devices Corporation (ENDECO) and the leachate detection services available from K-V Associates, the discussion of future devices is not appropriate here.

1.12 Specific conductance is used solely as a diagnostic characteristic of wastewater effluent and not as a contaminant. Phosphorus, sodium, nitrate-nitrogen and other constituents of interest in shoreline vegetative growth assessment or drinking water quality impacts are, of course, components of the total dissolved solids.

1.13 Refer to 1.11

1.14 Far more to the point is the alteration of background groundwater by wastewater additions. In an individual residence, groundwater is withdrawn and receives a certain amount of dissolved solids before recharge through a properly operating SAS. The extent of dissolved solids loading with residential usage is clearly influenced regionally depending upon whether the area is a hardwater or softwater source.

1.15 Your questions numbers 1.15 through 1.17 while understandably attempting to define the conductivity role lead to a rather superficial treatment of the types of groundwater reactions which occur as a result of SAS functioning. The assumption is made that the design of the septic system whether proper or not controls the characteristics of the groundwater discharge. In reality, the condition of the leachate from a system results from the chemical interaction of wastewater from the adsorption field with the chemical composition of the native groundwater.

Case 1: Crystal Lake, Michigan - see Kerfoot and Skinner (1981) Type of shoreline vegetation dependent upon groundwater flow pattern. In high pH regions, limited breakthrough of phosphorus.

Case 2: Marshland or bog region upstream of groundwater flow past SAS.

KVA, 1979, Investigation of Septic Leachate Discharges into Crooked Lake and Pickerel Lake, Michigan showed significant correlation coefficient (r = .64 and z value at 3σ = .78) between phosphorus concentration and conductance.

KVA, 1980, 1981, Ottertail Lake, Minnesota showed substantial phosphorus breakthrough during winter under high groundwater flow conditions and high frequency of plumes per residence in regions with bog regions upflow and adjacent to satellite lakes.

1.18 The formulae are based upon the coordinate system of numerical taxonomy (Sokal and Sneath, 1963). A treatment of the propagation of errors can be found in Chapter 6, "Estimation of Taxonomic Resemblance". The statistical basis has been reviewed by Sokal (1958) and Rohlf and Sokal (1963).

1.19 The original assertion of operation in salt water has not been found practical in normal field procedures. The conductance component proves useful when background conductivity of the surface water is less than 10,000 mg/l. If a stable significant signal can be obtained with a 2% solution of local wastewater added to background surface water, detection by coordinate signal processing is considered achievable.

1.20 I do not think I would ever make a statement like this. Whatever is a septic leachate outfall - an artesian well pipe discharge?

At the same time, however, the occurence of a stable ratio between fluorescence (of correctly-identified waste products) and conductance has been documented for:

1. Downstream profiling of outfall discharges into lakes and rivers (Winnepesauke and Green/Nest Lakes)
2. Septic leachate discharges in sandy shoreline soils (Crystal Lake), particularly in low pH regions (Cape Cod).
3. Shoreline locations with substantial groundwater inflow rates (greater than 10 feet/day flow).

1.21 As previously mentioned (see letter introduction), I believe the reference can only refer to the application of a leachate detector and a groundwater flowmeter to determine the appropriate lake level to minimize septic system discharges around a lake periphery. A result quite possibly achievable with a dammed or impounded lake with water level control.

1.22 This phrase is stretching the design of the instrument which was originally intended for lake shoreline scanning. However, the device has been used in closed -loop canals, low flow rivers, lake harbors, for well water scanning, and for investigation of wastewater treatment plant discharges into sand filter beds and directly into streams.

1.23 A central lake water sample constitutes the dilution water. Secondary effluent is a convenient sample free of particulates, representing a composite sample of the commonly utilized local fluorescent additives and the anticipated dissolved solids loading. The choice of secondary effluent also emphasizes the more refractory fluorescent compounds anticipated to be released from the aerobic leaching field component of a septic tank - leaching field on-lot septic system.

The choice of 10% is simply based upon chart paper gridding and field observation. The limit of detectability with a 10% solution full scale runs to .5%. Usual lake dispersion reduces a 100% groundwater source to less than a 5% signal in the overlying water.

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1.24 Again you are asking a leading question. A wide variety of sewage treatment plant processes exist as well as on-site septic systems. If you want to compare functioning, then consider a sewage treatment plant with a primary anaerobic treatment system and a secondary aerobic treatment cell to that of an anaerobic septic tank - aerobic leaching field/unsaturated zone percolation/groundwater on-lot system.

If a sewage treatment plant were to become completely anaerobic, there would be a significant change in its ability to degrade organic compounds, but virtually no impact on conductance. If the aerobic portion of the on-lot system becomes anaerobic, biodegradation (oxidation) of aromatic organic compounds is interfered with, allowing fluorescent refractory constituents to migrate through the soil. The extent of migration is dependent upon the prevailing groundwater condition (pH, redox potential composition), the rate of groundwater (residence time before discharge to lake).

1.25 I do not think the connection was intended, but I really am not the one to answer the question. Calibration is normally performed against the best local representative effluent sample. In order of priority, these are:

1. A solely domestic wastewater treatment plant;
2. A composite of local domestic package plants or clustered systems;
3. A composite of local septic system effluents (obtainable at distribution boxes, if possible).

Full scale adjustment to 1% effluent would be very difficult considering the normal range of signal to noise.

2. Instrumentation

2.01 Temperature correction is provided during calibration by use of the background lake water at its ambient temperature.

2.02 Convenience since both the fluorometric and conductance subunits employed analog circuitry. Inappropriate to comment on K-V Associates' device at this time.

2.03 Generally speaking, groundwater infiltration into nearshore lot regions will discharge within the top 3 feet of the water column. This assumption can be verified by in situ groundwater flow measurements. (modified Septic Snooper)

2.04 On the K-V unit, circuitry for the pump source is independent of the analytical system. Battery voltage is read from a meter located on the front of the unit. Flow rate is more likely to be diminished by plugging of intake screen with debris than battery fluctuation.

2.05 A long time constant is used as a buffer to separate short-term peaks from slowly-changing background water masses. The wide range simply reflects uncertainty of design with limited field experience at that time.

2.06 The limit of detection of the Septic Snooper depends upon background fluorescence, interferences, and conductance. A practical working limit of detection is .5% of standard effluent.

2.07 A powered boat is not used in normal surveying. The boat is often hand-pulled or pushed and serves to hold the leachate detector and operator. The motor is solely used to go from one transect region to the next. Turbulence from an outboard motor and vibration can provide serious sources of error.

2.08 Originally it was thought that a rotating screen could maintain the intake at a fixed distance from the lake bottom. Subsequent experience showed that it only resulted in enhancing turbidity and fouling of the intake. The idea was abandoned.

2.09 Question unclear.

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3. Operational Procedures

3.01 Initial scans have been performed at the northern end of John's Pond, Mashpee, MA to determine the best type of intake structure. The initial positive displacement pump with a vacuum hose intake was discarded for a centripetal sump pump because the former caused air bubbles to form in the line during blockage of the intake, creating interferences on the fluorescent and conductance channels.

Duplicate runs with different users provided similar profiles during surveying of John's Pond and the north shore of Ottertail Lake (KVA, 1980, 1981). The probe is moved back and forth over the bottom in a sweeping motion like a metal detector at an ideal distance of 2 inches above bottom.

Since a small vial of sample from each identified plume is required for later analysis, professional subjective judgement is substantially reduced.

3.02 A lot or topographical map of suitable scale (1 inch = 500 feet) is provided prior to the survey. The location of each residence is given a number and the number transcribed on the moving tape. As a back-check notes are taken of the color and structure of each residence, the plume location marked by a stake, and the specific fire number or address marked to verify position. The specific procedure depends upon the nature of the shoreline detail of the available maps and type of residential structures, but usually encorporates at least the mentioned items.

3.03 (1) Detailed Chemical Sampling: The Septic Snooper or the K-V modified leachate detector are considered to be solely a locational tool. Field chemical tests for phosphorus content, MBAS and conductance of groundwater (plume core) samples are performed in situ. Small quantity (5 ml) and large quantity samples of the overlying water and groundwater are taken at each location of a plume. The small sample is analyzed by laboratory fluorometric scanning to identify similarity to source effluent samples. The larger volume samples are analyzed by EPA standard procedures (EPA, 1975) for nutrient concentration, bacterial content, and often specific cations.

(2) Use of Groundwater Flowmeter: The leachate detector alone cannot identify the direction of groundwater flow. Shoreline groundwater-lake interactions can be complex and seasonal (Winter, 1978; Jaquet, 1976). With knowledge of groundwater flow rate

(a) The probable location of source can be identified. For instance, a flow at 45° to the shoreline will cause a plume to emerge on the neighbor's lot, not where the source is.

(b) Locations of exfiltration where system-well short-circuiting is more likely can be identified for well water testing.

(c) Evaluations of the vertical location of porous strata likely to transmit effluent to the lake can be performed.

(3) Modifications to the Leachate Detector to Allow 2-Channel Readout Recording: Fluorescence and conductance are simultaneously recorded on a dual channel recorder system. At the same time, a separate recorder provides a continual analog plotting of the cojoint signal.

(4) Coordination with Sanitary Survey: Determinations of seasonal use of septic systems are desirable when studying highly seasonal resort areas. Type of septic system and location on lot provide useful accessory information.

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4. Usefulness as a Planning Tool

4.01 Again, the information provided by the chart recording of the leachate detector provides information on the location of plume discharge along the shoreline. A coordinate rise of fluorescence and conductance in the same proportion expected with local effluent identifies a probable plume. Verification is performed by a combination of laboratory and field analysis.

4.02 Peaks in conductance are usually considered nonsignificant. Depends upon the level of confidence desired - 3 σ for 99%, 2 σ for 95%. Signal to noise ratio indicates a limit of detection of about .2% effluent.

4.03 A peak of fluorescence was found to occur without conductance with sludge deposits or the so-called "dormant" plumes (Kerfoot and Skinner, 1981). If spectral scanning verifies an effluent source, the location is considered as being an intermittant plume. A very similar limit of detection of conductance (from .1 to .2% effluent) occurs.

4.04 If both occur in the same ratio as effluent, and exhibit a spectral scan equivalent to effluent, the plume is considered verified. However, whether a threat of localized eutrophication or bacterial infection is likely, can only be determined after analysis.

4.05 See Section 3.02 and 3.03.

4.06 The reporting involves (1) a lot mapping of discharges and (2) a technical report. The two types of presentation involve coding of type of discharge involved or a projection of plume sources and strength along the shore in addition to a technical report.

4.07 The approximate 5-year breakdown of funding source would yield:

EIS funds	60%
201 Construction Grants	20%
Local/Regional Planning	10%
Private Funds	10%

4.08 Yes, for example see:

Crystal Lake study
Nettle Lake study
Salem Lakes study
Lake Hopatcong study

4.09 Additional information included by KVA: The usefulness of groundwater flow mapping and leachate surveys as a planning tool can become an important factor in residential development surrounding groundwater-based lakes, planning for on-lot well water systems and SAS systems, and for municipal well water protection. Examples of these applications can be provided, if requested.

5. Cost

5.01 Usually two persons are involved in a survey team. During a survey, the equipment operator rides in a boat while the field assistant directs the boat and is responsible for water quality analysis of identified probable plumes. The length of time depends upon the shoreline length involved, the nature of the shoreline, the detail of investigation of identified plumes, and well sampling, if included. Generally, a field team can average 3 to 5 shoreline miles per day, not counting set-up or demobilization time. Field studies commonly involve one to two weeks' effort for 20 shoreline mile lake areas. Analysis is usually completed within a month and report preparation within 6 weeks of thestart of field work.

5.02 Fixed cost. See enclosed price sheet for 1980. Higher costs would result from large number of docks, convoluted shorelines, rocky shorelines of variable water depth and difficult footing.

5.03 Yes, we currently provide operator training with the groundwater flowmeters and intend to do so with the leachate detectors. Two days' field and laboratory program ($250/day). Consulting services are considered to be available with any instrument purchase, if necessary.

5.04 Lease-purchase arrangements are currently available with existing equipment and would be planned for future equipment. Fees are negotiable, but often run $600/week.

K-V ASSOCIATES, INC.
Falmouth, MA

May 26, 1981

SCOPE OF WORK

1. Conduct a shoreline leachate survey and groundwater mapping of sections of lake.

2. Scan the shoreline to identify and map leachate plumes entering the lake from failing septic systems, catagorizing by 3 types (surface, groundwater-dormant, groundwater-erupting). The septic leachate detector will be calibrated against local effluent from a nearby sewage treatment plant.

3. Measure the direction of groundwater flow in areas where plumes are detected and indicate which residences the plumes appear to be originating from (using fire number, owners name or other method) by projecting zone of contributions back from position of erupting plume.

4. Using a groundwater well point sampler, vertically profile subsurface plumes and sample core regions of suspected groundwater plumes.

5. Do field screening of water samples for detectable levels of orthophosphate and detergents.

6. Perform chemical analyses on field samples indicating positive results on field screening. This will include analysis of orthophosphate, ammonia-nitrogen conductance, and detergent (MBAS).

7. Perform bacterial analyses of water samples, including fecal coliform and fecal streptococcus, if possible.

8. In areas where the groundwater flow pattern is away from the lake, monitor the direction of groundwater flow and sample groundwater beyond the septic system to identify possible leachate plumes flowing away from the lake.

9. The locations of septic leachate plumes and direction of groundwater flow will be mapped.

10. Results should be summarized in table form indicating residents with malfunctioning septic systems.

K-V ASSOCIATES, INC. May 26, 19

QUOTATION

Septic leachate survey and groundwater flow mapping
Total lake shoreline (20 miles)
Residential sections only

700 RESIDENTS	FIELD	REPORT	TOTAL	PER RESIDENT
A. Field Analysis + Bacteria testing (1)	$10,411.	$2,500.	$12,911.	$18.44
B. Lab. Analysis + Bacteria testing (2)	$12,351.	$2,693.	$15,044.	$21.49
C. Field Analysis - No Bacteria testing (3)	$ 9,600.	$2,400.	$12,000.	$17.14
350 RESIDENTS				
A. Field Analysis + Bacteria testing	$ 8,889.	$1,970.	$10,859.	$31.03
B. Lab. Analysis + Bacteria testing	$ 9,889.	$2,000.	$11,889.	$33.97
C. Field Analysis - No Bacteria testing	$ 9,390.	$1,950.	$11,340.	$32.40
200 RESIDENTS				
A. Field Analysis + Bacteria testing	$ 6,700.	$1,580.	$ 8,280.	$41.40
B. Lab. Analysis + Bacteria testing	$ 6,911.	$1,650.	$ 8,561.	$42.81
C. Field Analysis - No Bacteria testing	$ 6,800.	$1,500.	$ 8,300.	$41.50

(1) Includes work outlined in scope of work without additional laboratory analyses indicated in (2).

(2) Includes full range of field testing as presented in scope of work plus laboratory analysis of orthophosphorous (PO_4-P) Total Phosphorus (PO_4-P), ammonia-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), organic nitrogen (ORG-N), PO_4-P detergent and conductance.

(3) Includes only field water quality analysis - Orthophosphate-phosphorus, ammonia-nitrogen (NH_4-N) detergent, conductance; no. coliform bacteria analysis.

K-V ASSOCIATES, INC. May 26, 1981

QUOTATION

Random sampling survey, Lakeview Township
Individual well supplies
Septic leachate "Short-circuiting"

BACKGROUND

Leachate from on-lot septic systems form discrete plumes which flow downstream with the prevailing groundwater flow. If such a plume encounters a well intake of sufficient strength, the well ir impacted and may have to be abandoned. With a requirement of 100 foot separation between well intake and on-lot leaching system, the possibility of bacterial contamination in medium sandy soils is remote. Most reported impacts originate from chemical sources, notably detergent, nitrate-nitrogen, or salt contamination. The expected frequency of subsurface failure can be approximated by a probability distribution. Random sampling of residents can establish the observed frequency to allow comparison with theoretical probabilities.

1. Brief description of groundwater flow in region.

2. Selected sampling of individual well supplies.

3. Preliminary plotting of frequency of observed occurrences of "short-circuiting" versus hypothetical frequency.

4. Verification of wastewater presence by fluorescent scanning-organic analysis.

5. Chemical analysis of water samples indicating "short-circuiting" TP, ortho-P, NH_4-N, NO_3-N, Fe.

SAMPLE SIZE	ANALYTICAL	LABOR	TOTAL COST	COST PER RESIDENT
50 residents	$504.00	$2000.	$2504.00	$50.00
50-100	$756.00	$3000.	$3756.00	$37.56
100-200	$1260.00	$4000.	$5260.00	$26.30
300-400	$3360.00	$5000.	$8360.00	$20.90

6. Comparison with Other Techniques

6.1 Yes. The original Crystal Lake study involved detailed sanitary studies of individual lots, special studies of aquatic productivity and detailed investigation of individual plume sources to substantiate the accuracy and limitations of the leachate detector (for summary, see Peters and Krause, 1980; for details see draft Environmental Impact Statement, Case Study Number 1, Crystal Lake Area, Sewage Disposal Authority, Benzie County, Michigan). Another study of Lake Geneva and Como Lake, Wisconsin showed a close correlation between fecal coliform/fecal streptococcus ratios for tributaries and the presence of wastewater discharges indicated by the leachate detector (KVA, 1979).

6.2 A complete survey provides the community with a direct report of the extent of existing discharges of septic-related wastewater into the lake from along the shoreline. It provides a means of identifying entry location, and if suitable soil conditions exist, a means of identifying the source of contamination for remedial action. No other techniques now in practice can readily identify and locate chemical discharges of septic system origin which flow through groundwater. The use of monitoring wells is impractical considering the length of shoreline usually involved and the discrete localized nature of plumes. The addition of commercial dyes to the septic system is impractical due to their soil adsorption and scheduling time for sampling for detection unless highly coarse substratum is involved.

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swanson environmental, inc.

24158 Haggerty Road
Farmington Hills, Michigan 48024
(313)478-2700

July 7, 1981

Ms. Cynthia Ernst
Junior Analyst
Urban Systems Research &
Engineering, Inc.
36 Boylston Street
Cambridge, MA 02138

Dear Ms. Ernst:

Enclosed please find our response to the Septic Snooper questionnaire. I have answered the questions as completely as possible.

If you have any questions, please do not hesitate to contact me.

Thank you for the opportunity to serve Urban Systems Research & Engineering, Inc.

Very truly yours,

SWANSON ENVIRONMENTAL, INC.

Jill Wright

Jill Wright
Environmental Compliance Specialist

/th

encl.

1.00 Theory

1.01 Yes.

1.02 The fluorescing compounds are considered to be both contaminants and indicators of contamination. The contaminants of concern are phosphorus, nitrogen, and fecal coliform.

1.03 Whiteners and surfactants.

1.04 We cannot provide documentation, although it is available through a literature search. Our work is based on information contained in the literature.

1.05 Same as above.

1.06 There are two main ways in which the fluorescing compounds are removed from the wastewater:

Primary: phosphorus and nitrogen adhere to the soil particles.

Secondary: dilution and dispersion may occur and, therefore, will not show up in the tested water.

Fecal coliform will not adhere to the soil particles, but if the distance between the SAS and the groundwater and/or surface water is great enough, the fecal coliform will die and, therefore, not be evident in the water tested.

1.07 Yes. Literature search can provide documentation.

1.08 The compounds can be transmitted to the groundwater in a number of ways.

1. In an improperly operating system, the soil may become saturated with water so that it is part of the groundwater system. This may occur when the water table is unusually high.

2. In an overloaded system, the bottom gravel in the filtration bed can become clogged and the wastewater stream cannot be cleansed as it goes through. The water will then seep into the groundwater unfiltered.

3. Surface ponding may occur. The water will flow across the surface and seep into the groundwater.

The contaminants are transmitted in the same manner.

1.09 The compounds travel with the groundwater into the lake. The contaminants of concern behave in a similar method.

1.10 Once in the surface water body, the fluorescing compounds behave in the following manner:

Organics:

surfactants - disperse and become diluted, then disappear;

phosphorus and nitrogen - taken up by the plants and get into the system, where they act to increase plant life and may cause entrophication of the lake.

Inorganics:

sodium and chloride - disperse into the system.

1.11 No, not necessarily. Chlorides do not adhere to soil particles. They flow freely through the soil.

1.12 Same question as above.

1.13 In a properly operating SAS, the groundwater will be lower in conductivity. Literature research can provide documentation.

1.14 Yes.

1.15 SEI has not yet used the Septic Snooper in a saline system. Statements concerning use in saline systems are based on factory representation.

2.00 Instrumentation

2.01 SEI has not performed experiments to document consistency of temperature; temperature measurements are not taken consistently; corrections are not made for varying temperature.

2.02 SEI attempts to travel as close to shore as possible, depending on water depth. Approximately 90% of the time, travel is within five feet of the shore.

2.03 The power for the pump is supplied by a 12 volt battery. Variations in the power source have very little effect on the consistency of the water supply. The lowest limit the battery runs on is 11-1/2 volts, which is within the recommended level.

2.04 I am not sure exactly how to answer this question. The sensitivity varies a lot. The Septic Snooper normally operates at very near maximum sensitivity levels. It is possible to measure a change in sensitivity of 5 muohs for inorganics. This change can be consistently detected.

2.05 In shallow water, one person either pulls or pushes the boat. In deeper water, either an electric trolling motor is used or the boat is rowed. Because the boat moves at less than 1/2 mph during actual scanning, boat velocity has very little effect on the flow rate.

The device is not affected by the noise of an outboard motor, but it is affected by short wave radio. The boat does not have a propellor, and the pump is held ahead of the motor, so it is not affected.

2.06 The screen on the intake device does not stabilize sensitivity.

2.07 There is a 3 - 4 second lag in detecting conductivity, and a 10 - 12 second lag in detecting organics. Once the indicators appear on the meter, the boat must go back approximately 10 feet to detect the plume.

3.00 Operational Procedures

3.01 The sampling probe is held 6 inches to one foot above the bottom of the lake. This is necessary to avoid drawing up soil particulates and plant debris. To the best of our knowledge, there have not been double blind tests conducted.

3.02 The continuous graphic output is directly correlated to maps. Large scale shoreline maps are carried on the boats, and SEI personnel make their notes directly on the maps.

3.03 SEI assigns the same people to do the field survey and write the report. Also, SEI personnel are trained to follow procedures exactly.

4.00 Usefullness as a Planning Tool

4.01 The information on the tape is interpreted immediately on site, and takes into account soil type, topography, and background water quality.

4.02 Peaks in fluorescence with no response in conductivity are observed. In most cases this is not considered to be an indicator of septic discharge. Clearwater discharges have increased conductivity while organic levels decline.

The least detectable signal is approximately 5 units for conductivity and 40 - 50% above background levels for organics.

4.03 Same as above.

4.04 Peaks in both conductivity and fluorescence usually indicate that septic discharge is occurring. Levels of 30 - 40% over background can be detected, but levels over 100% of backgrond are preferred. Detectable levels can vary depending on sensitivity.

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4.05 Other data sources used in our studies are:

background water quality information

hydrology

regional groundwater flow patterns

local groundwater flow patterns

soil types

topography

residential frequency (i.e. permanent vs. temporary residents vs. commercial development)

This data is used only as background information. Our actual analysis is only of data generated from the septic leachate survey.

4.06 SEI uses reports to transmit our analyses to our clients. A sample Table of Contents is attached.

4.07 Approximately 90% of our studies have been funded by 201 Construction Grants. The other 10% have been funded by lake associations, planning agencies, etc.

4.08 I believe that the results of our surveys have been used in conjunction with other studies, but SEI has not done so nor have we been informed as to the results of such studies.

5.00 Cost

5.01 A minimum of two (2) people and a maximum of four (4) are assigned to a survey team. In a two-person team, one person is responsible for controlling the boat and guiding the probe. The other person keeps track of the location, observes the equipment, directs the person holding the probe, and collects surface water and groundwater samples.

When necessary, two boats (4 people) go out on a survey. The second boat collects the groundwater samples.

Frequently a particular part of the shoreline will be traversed more than once, either immediately to locate a plume, or at a later date to substantiate the initial results.

One (1) shoreline mile, including analysis and report, will take approximately three days.

5.02 Services are priced on a cost plus fixed fee basis. Sample unit costs are attached. Conditions which would result in higher than usual costs include heavy weed growth and/or intense docks and cottage development.

5.03 SEI does provide operator training for clients interested in purchasing equipment. The training takes one day, and the cost is incorporated into the equipment purchase price. Consultation services are provided.

5.04 SEI does not rent out equipment.

6.00 Comparison With Other Techniques

6.01 Double blind tests have not been conducted.

6.02 Information gained from a complete survey includes:

1. A very detailed, complete evaluation of the entire shoreline area of concern.

2. An evaluation of human health related problems resulting from septic seepage.

3. It is possible to calculate the nutrient loading and subsequent impacts of eutrophication of the lake due to phosphorous loading, and to incorporate these results into a nutrient budget.

SAMPLE TABLE OF CONTENTS

I. INTRODUCTION

II. PROCEDURES

III. RESULTS

IV. CONCLUSIONS

ATTACHMENTS (detailed maps of study area)

CLIENT LIST

Location of Project	Client
Lake Winnebago, Neenah, Wisconsin	Davy Engineering Company
Indian Lake, Logan County, Ohio	Floyd Browne Associates, Ltd. Marian, Ohio
Lauderdale Lakes, Walworth County, Wisconsin	Lauderdale Lakes Protection Association Walworth County, Wis.
Lake Waconia, Carver County, Minnesota	Ellison-Philstrom- Ayers, Inc. St. Paul, Minnesota
Pierson's Lake, Carver County, Minnesota	Ellison-Philstrom- Ayers, Inc. St. Paul, Minnesota
Lake Bavaria, Carver County, Minnesota	Ellison-Philstrom- Ayers, Inc. St. Paul, Minnesota
Reitz Lake, Carver County, Minnesota	Ellison-Philstrom- Ayers, Inc. St. Paul, Minnesota
Lake Auburn, Carver County, Minnesota	Ellison-Philstrom- Ayers, Inc. St. Paul, Minnesota
Lake Minnewashta, Carver County, Minnesota	Ellison-Philstrom- Ayers, Inc. St. Paul, Minnesota
Cedar Lake, Carver County, Minnesota	Ellison-Philstrom- Ayers, Inc. St. Paul, Minnesota
Dixon Lake, Otsego County, Michigan	Williams & Works Grand Rapids, Michigan
Opal Lake, Otsego County, Michigan	Williams & Works Grand Rapids, Michigan

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CLIENT LIST

Location of Project	Client
Long Lake, Otsego County, Michigan	Williams & Works Grand Rapids, Michigan
Horseshoe Lake, Otsego County, Michigan	Williams & Works Grand Rapids, Michigan
Perch Lakes, Otsego County, Michigan	Williams & Works Grand Rapids, Michigan
Heart Lake, Otsego County, Michigan	Williams & Works Grand Rapids, Michigan
Fawn Lake, Otsego County, Michigan	Williams & Works Grand Rapids, Michigan
Otsego Lake, Otsego County, Michigan	Williams & Works Grand Rapids, Michigan
Park Lake, Columbia County, Wisconsin	General Engineering Company, Inc. Portage, Wisconsin
White and Duck Lakes, Oakland County, Michigan	Johnson & Anderson, Inc. Pontiac, Michigan

APPENDIX D

REVIEWERS COMMENTS

KENT STATE UNIVERSITY
KENT, OHIO 44242

DEPARTMENT OF
BIOLOGICAL SCIENCES
(216)672-3613

November 9, 1983

Ms. Patricia L. Deese, P. E.
Urban Systems Research and Engineering, Inc.
2067 Massachusetts Avenue
Cambridge, Massachusetts 02140

Dear Ms. Deese:

I enclose my report on your manuscript entitled "Shoreline Surveys of Subsurface Effluent Plumes". You have done a thorough and accurate analysis of the current state of instrumentation for SEPD surveys.

If I can be of further service, please write or call.

Sincerely,

G. Dennis Cooke
Professor

GDC:jf
Enclosures

Evaluation of "Shoreline Surveys to Subsurface Effluent Plumes"
(Prepared by P. L. Deese, P.E.)

I find this report to be a thorough, fair, complete, and accurate evaluation of the Septic Snooper. The author has raised excellent questions, tested them with the data at hand, and formed firm conclusions and recommendations. The following comments may be of value in preparing the final draft.

1) EPA reports have an unusual format in that Conclusions are given first. I urge the author to develop a Discussion section at the end to review the data and conclusions.

2) The Literature Cited section is woefully incomplete and references are not directly cited in the test. I never did find references 1-12. Since this is a scientific report, it should be written as one.

3) On p. 10, a statement is made (beginning 7 lines from the bottom) that needs investigation. For example, I and others (Cooke et al., 1978, EPA-600/3-78-033. Effects of diversion and alum application on two eutrophic lakes) have reported that septic tank effluent actually moves to the ground surface and is easily carried by overflow runoff. Leach fields plug with organic matter, making downward percolation impossible.

4) Exhibit 4-2 is difficult to understand since the axes are not clearly labelled and the "pr." (=probability?) values are very strange.

5) Some references:

   a. Kerfoot, W. B. and S. M. Skinner. 1981. Septic leachate surveys for lakeside sewer needs evaluation. J. Wat. Poll. Cont. Fed. 53:1717.

   b. Lee, D. R. 1972. Septic tank nutrients in groundwater entering Lake Sallie, Minnesota. M. S. Thesis, Univ. of North Dakota (note: Lee's thesis and subsequent papers are among the real basic works in this area).

c. Polkowski, L. B. and W. C. Boyle. 1970. Ground water quality adjacent to septic tank-soil absorption systems. Wisconsin Dept. of Natural Resources, Madison. 75 pp.

6) An item which was missed or not emphasized in the criticism is the impact of macrophytes on littoral water chemistry and thus on the values reported by the Septic Snooper. These plants are very abundant in many lakes especially eutrophic ones, and continually senesce or slough tissue to the water. Much of this loss of organic matter is as dissolved organic matter (DOM), some of which may interfere. This idea is potentially an important criticism since most groundwater discharge to the lake occurs in this littoral zone. It may contain DOM from septic leachate which is camouflaged by DOM from intense macrophyte senescence (early August onwards).

7) I have noted a few typographical errors. The word "data" is always plural.

TETRA TECH, INC.
3746 MT. DIABLO BOULEVARD
LAFAYETTE, CALIFORNIA 94549
SUITE 300 • (415) 283-3771

November 2, 1983

Patricia L. Deese
Urban Systems Research & Engineering, Inc.
2067 Massachusetts Avenue
Cambridge, Massachusetts 02140

Dear Patricia:

Although your report arrived in my office on October 17, I did not return until October 31 and consequently was unable to review the report until now. My comments are handwritten on the document. Although considerable editing of typos is needed, that task was not my intent. I have attached a bill.

Sincerely yours,

Donald B. Porcella, Ph.D.
Principal Scientist
Environmental Systems Engineering

DBP/jw
Enclosure

1. For an average family of 4 and 100gpcd and 24 hours of waste flow from a leach field, the typical flow into a lake would be 0.28 gpm or 1.07 liters per minute at steady state. In my judgment, it would be nearly impossible to detect consistently such a flow or chemical differences generated by such a flow in a lake. Given a cross-sectional area of 10am 2/1 (drain = 3.6cm), this would result in a velocity of about 1.7cm/sec. changes in any of these assumptions would tend to make this less detectable, as a rule. A good paper relating to ground water quality and in-flow along entraphic lakes.[1]

2. We did some work on chemical measurements as an aid to identifying septic inputs to a stream. The attempt was a fairline (Meyers etal). I am convinced that although septic effluent impacts on lakes can be substantial (Cooke et.al.), they are not measurable by such techniques. Mass balance techniques are more useful.[2]

3. Velocities in littoral areas of lakes are quite rapid and mixing would occur very rapidly. Although I do not have references on this subject, I think it would strengthen the theoretical basis for rejecting assumption #2. Another consideration is that the data in Appendix A on Otter Tail Lake would represent one of the most favorable situations possible for demonstrating its effectiveness. Most lakes are not as well situated (my assumption - ?). However, these data do not satisfactorily support the contentionsof the vendor.

---

[1]Lee, D.R. 1978. A device for increasing seepage flow in lakes and estrainers. Linnol. Oceanogr. 22:140-147.

Note, the highly variable characteristics of the seepage inflow in Lee's paper (p.146, Table 2).

[2]Mey4rs, D.W., E.J. Middlebrooks, & D.B. Porcella. 1972. Effect of Land Use on Water Quality: Summit Creek, Smithfield, Utah. PRWR 17-1. URL Utah State University, Logan, UT 84322.

Cooke, G.D., et. al., 1973. Some Aspects of Phosphorous Dynamics of the Twin Lakes Watershed. In Modelling the Entrophication Process. (E.J. Middlebrooks, et al Editors) Ann Arbor Press, Ann Arbor, MI pp 57-72.

University of Notre Dame *Notre Dame, Indiana 46556-0369*

Department of Biology *General Office (219)239-6552*

25 October 1983

Dr. Patricia L. Deese
Urban Systems Research and Engineering, Inc.
2067 Massachusetts Avenue
Cambridge, MA 02140

Dear Dr. Deese:

Enclosed please find:

1. My review of the report "Shoreline Surveys of Subsurface Effluent Plumes".
2. A reprint of a publication cited in my review.
3. The draft report, with penciled marginalia.
4. A copy of my C.V.
5. My bill for one day's consulting.

I shall look forward to hearing from you.

Sincerely,

Stephen R. Carpenter

Dr. Stephen R. Carpenter
Assistant Professor

Review of "Shoreline Surveys of Subsurface Effluent Plumes"

Dr. Stephen R. Carpenter
Department of Biology
University of Notre Dame
Notre Dame, IN 46556

25 October 1983

1. I am aware of no evidence that groundwater plumes cohere and remain detectable for any distance in lakes. Storm sewer and stream inputs to lakes may remain discrete and identifiable if their temperature is very different from that of the lake water (Bryson and Suomi 1951, Prentki et al. 1979). However, the volume and flow rate of these inputs are much greater than those of groundwater, hence they are diluted more slowly. Ground water plumes should be less cohesive than storm sewer or stream inputs to lakes. The integrity of ground water plumes should depend on the temperature differential between the ground water and lake water.

2. Many fluorescent compounds occur naturally in lake water, e.g. humic substances and algal pigments. It is conceivable that detergents and whitening agents could be discriminated from natural fluorescent compounds by careful selection of excitation and monitoring wavelengths. However, on the basis of the documents at hand I see no evidence that the background data needed to select appropriate wavelengths have been gathered. Studies comparing the fluorescent properties of sewage leachate and natural organic matter are needed to validate the proposed methodology.

3. The proposed "unique and stable ratio" between fluorescence (F) and conductivity (C) suggests that $F/C = k$, a constant, or $F = kC$. That is, a plot of fluorescence versus conductivity for a population of septic tank samples should lie on a straight line of slope k, distinct from data points based on lake water. It seems that the data on hand would allow

one to construct such a graph and test the hypothesized relationship.

4. Based on the preceding points, I conclude that the proposed technology is not yet validated. Further research is needed, as discussed in the report. In particular, I suggest

(i) dye tracer studies to determine the physical integrity of plumes of contaminated groundwater.

(ii) comparative studies of septic tank and natural organic compounds with respect to fluorescence intensity as a function of excitation and measurement wavelength.

5. In view of the probable importance of temperature to the integrity of groundwater plumes, addition of a temperature sensor to the probe of the "Snooper" is recommended.

References

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Prentki, R.T., M.S. Adams, S.R. Carpenter, A. Gasith, C.S. Smith, and P.R. Weiler. 1979. The role of submersed weedbeds in internal loading and interception of allochthonous materials in Lake Wingra, Wisconsin, U.S.A. Arch. Hydrobiol./Suppl. 57: 221-250.

APPENDIX E

LIST OF PERSONS CONTACTED DURING THIS STUDY

ALPHABETICAL LIST OF PERSONS CONTACTED DURING THIS STUDY

Name Address	General Background	Questionnaire*	Interview**
Roger Akeley NH Lakes Region Planning Commission	Yes		
Dan Armstrong George Washington University			T
Ron Arsenault ENDECO, Marketing Manager		V	P
Bob Borpahle Ellison-Philstrom-Ayer Inc.	Yes		
Edward Brainard, II ENDECO, President		V	P
John Dickey Rist-Frost Associates	Yes		
Fred Elkind NH Water Supply/Pollution Control	Yes		
Ginny Garrison Vermont Department of Environmental Conservation	Yes		
William Kerfoot K-V Associates, Inc.		W	P
Al Krause EPA Region V			P
Don LaVoie Reike, Carroll, and Muller	Yes		
Ron Manfredonia EPA Region I	Yes		
James McCarthy Harvard University	Yes		

ALPHABETICAL LIST OF PERSONS CONTACTED DURING THIS STUDY

Name Address	General Background	Questionnaire*	Interview**
Bill Mellen Lake County Health Dept.	Yes		
Francois M.M. Morel M.I.T.	Yes		
Gerry Peters WAPORA		V	T
Mike Rapacz Interdisciplinary Engineers and Planners	Yes		
Ted Rockwell EPA Region V			P
John Stewart Maier, Stewart and Associates	Yes		
Natalie Taub EPA Region I	Yes		
Jill Wright Swanson Environmental, Inc.		W	

* W = written; V = verbal
** P = in person; T = by telephone